NASA CR 179603

Design, Development and Deployment of Public Service Photovoltaic Power/ Load Systems for the Gabonese Republic

IN-44

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Final Report

Contract No. DEN 3-347

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William J. Kaszeta
Solavolt International

(NASA-CR-179603) DESIGN, DEVELOPMENT AND DEPLOYMENT OF PUBLIC SERVICE PHOTOVOLTAIC POWER/LOAD SYSTEMS FOR THE GABONESE REPUBLIC Final Report (Solavolt International) 235 p Avail: NTIS HC A11/MF A01 CSCL 10B G3/44

N87-23030

Unclas 0076804

APRIL 1987

Prepared For

NASA

National Aeronautics and Space Administration
Lewis Research Center

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APPENDICES

FINAL REPORT

Section 1. INTRODUCTION

This report describes the five different types of public service photovoltaic power/load systems installed in the Gabonese Republic.

The objectives of this contract were to design, fabricate, deploy and evaluate the performance of public service photovoltaic (PV) power/load systems (hereinafter referred to as systems) in four (4) villages in the Gabonese Republic (GR). The systems were to be suitable for replication in Gabon and other developing countries.

The systems supplied under this contract are part of a project designed to demonstrate the suitability (i.e., cost-effectiveness and reliability) of photovoltaics for rural public service applications in developing countries. The results of these demonstrations will be used by the GR as well as other developing country decision makers to assess the technology and to assist them in deciding how, when and where photovoltaics should be used to meet electrical energy needs in their rural sectors. As such, the systems design goals are cost effectiveness, reliability, modularity, ease of operation and repair, and low maintenance.

The systems are capable of providing reliable cost-effective DC power and operate in a stand-alone mode (i.e., no back-up power systems). Provisions were included for measuring and recording all data required to evaluate system performance in the field. All load devices powered by the PV system were provided by the contractor. Wherever possible, local labor was employed during installation and checkout.

A total of 17 systems were installed in Gabon as part of this project. The systems are located in four (4) villages. Each of the villages has a dispensary system, school system, water system and village light system. In addition, the village of Bolossoville has a community building system.

This report describes the village settings, the systems, performance results and some of the problems encountered and overcome in the execution of this project. Most of the systems performed well, but some of the systems had problems due to failure of components or installation errors. The project was reasonably successful in collecting and reporting data for system performance evaluation to guide GR officials and system designers involved in village power applications in developing countries.

Section 2. VILLAGE DESCRIPTIONS

The villages are located in four (4) different regions of Gabon and were chosen to represent the major climatic and political regions of the country. Gabon is best described as a tropical rain forest although there is a dry season from May until late September.

Donguila is located in the Northwest region approximately 47 km from Libreville, the capital city. The village is on a ridge overlooking the Estuary of Gabon. Of the four sites, Donguila has the greatest need for a reliable water supply, due to very poor natural water supply and the presence of a boarding school there. Travel time is 1-3/4 hour from Libreville. TV reception from Libreville is good when using an outside antenna elevated 6 meters. Drawing number 79CSB28001B, Donguila Village Plan (Appendix A), shows the location of all of the systems in this village.

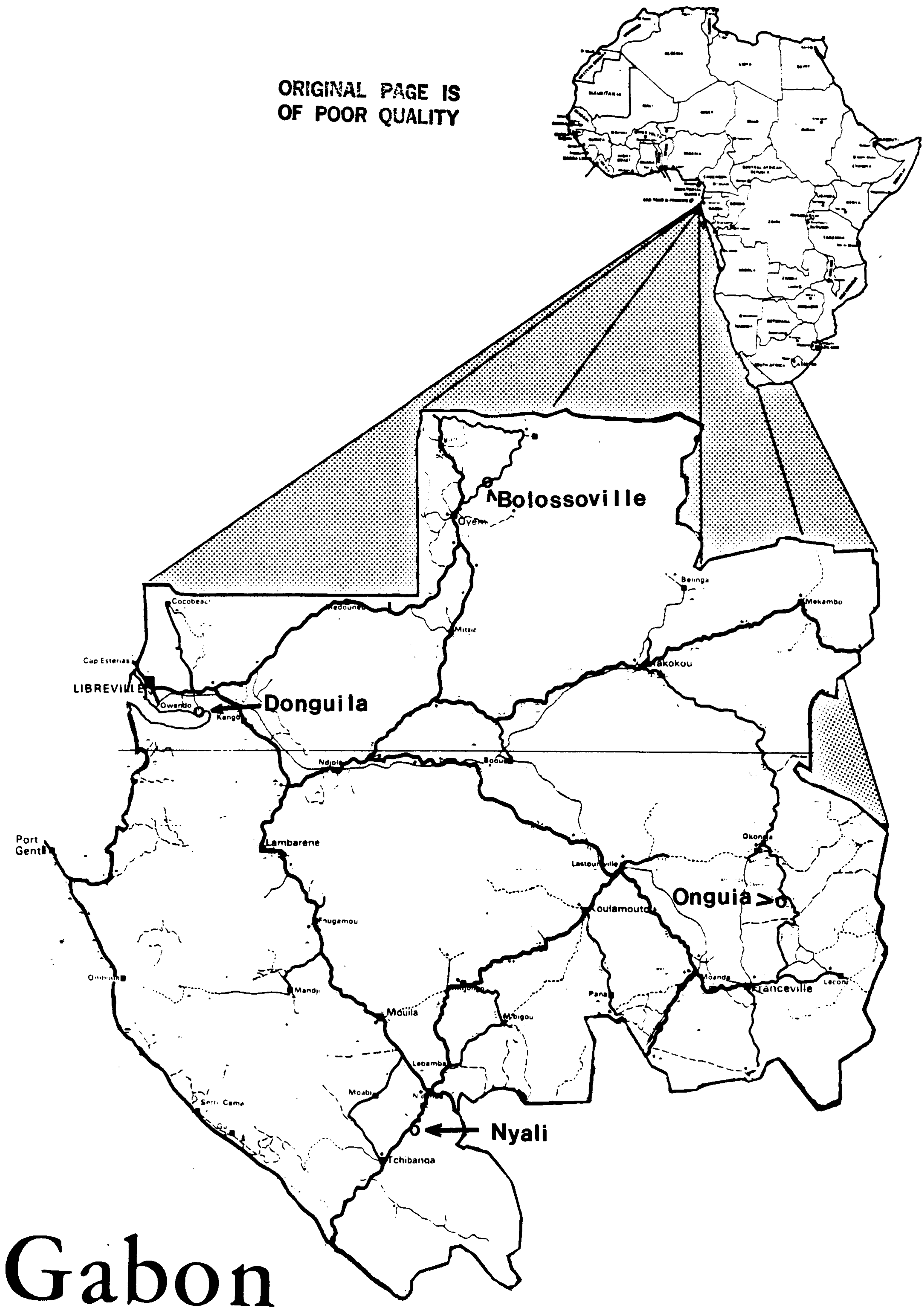
Nyali is located at the edge of a broad valley in the southwest part of the country. The village is unique in that it is the site of a long-term rice growing experiment sponsored by the Chinese. Water is abundant, the water well being the shallowest but most productive of the four (4) project village wells. The village lies in gently rolling terrain along the edge of a wide valley. The water tank was located on a hill above the village.

Nyali is a one-hour trip over a good dirt road from Tchibanga. TV reception for Nyali will be unavailable for many years. There is presently a desire to extend water availability to the next village just east of the Nyali school. Drawing number 79CSB28034B, Nyali Village Plan (Appendix A), shows the location of all systems at this site.

Onguia-Bougandji is located in the less tropical southeast part of the country. This is the most primitive of the villages and has been the site of U.S. Peace Corps activity. The water well is in a deep ravine outside of the village and required extensive work to properly place water pipes. This village is two hours from Franceville by good road. Drawing 79CSB28016B, Onguia-Bougandji Village Plan (Appendix A), shows the location of the systems in this village.

The largest village is Bolossoville, located in the northeast not far from Cameroon. This village is spread out along a road for about 1-1/2 km. The region is hilly and the village is along a crest of a hill. The water well is the deepest and yields less than two (2) cubic meters per hour from an 85-meter depth.

Bolossoville is one hour's travel from Oyem. A TV station is planned for Oyem, and an antenna mounted on a 12-meter pipe should provide suitable reception. Drawing number 79CSB28051B, Bolossoville Village Plan (Appendix A), shows the location of all of the systems at this site.


Bolossoville
Oyem
Belinga
Mekambo
Mitzic
Makokou
Cap Esterias
LIBREVILLE
Owendo
Kango
Donguila
Ndjole
Booue
Port Gentil
Lambarene
Okondja
Lastourville
Koulamoutou
Onguia
Fougamou
Mandji
Moanda
Franceville
Mouila
Mbigou
Lebamba
Moabi
Setti Cama
Nyali
Tchibanga
Gabon

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Section 3. SYSTEMS AND INSTALLATIONS DESCRIPTIONS

3.1 Systems Descriptions

From the beginning, every effort was made to design all aspects of the systems for reliable, cost-effective operation. Before developing the request for proposal (RFP), NASA personnel visited the villages and gathered a substantial amount of site data. In the same month that the RFP was released, Solavolt was visiting Gabon for other business and gathered additional information that was used in the systems design. Much of this information was furnished by Ceca Gadis, Solavolt's representative, located in Libreville, Gabon. For this project, Solavolt subcontracted with Ceca Gadis for the installation and operational support tasks. Ceca Gadis also participated in the design process and contributed a large amount of background data on how to best design, install and maintain these systems.

The first task in this project was to visit all villages to gather the additional detailed site data required to complete the system designs. In addition to the village visits, much time was spent in meetings with the Ministry of Energy and Resources Hydraulic (MERH), Society of Water and Energy in Gabon (SEEG, the national electric and water utility), and various potential equipment suppliers.

3.1.1 Dispensary Systems

Each of the dispensaries was provided with the following load equipment:

- 4 - 40 watt Fluorescent Lights
- 1 - Ceiling Fan
- 1 - Porch Light (low-pressure sodium vapor)
- 1 - Refrigerator/Freezer (R/F) for vaccine storage.

The dispensary system control sub-system provides for load shedding of the lights and fan if necessary to conserve energy for the refrigerator. Instrumentation to monitor operation of the refrigerator and porch light was provided and is described later in this report.

3.1.2 School and Community Center Systems

Each of the schools was provided with nine (9) 40-watt fluorescent lights. The schools in Donguila, Nyali and Onguia-Bougandji were provided with a color television and a video cassette recorder/playback unit (VCR). In Bolossoville, the TV and VCR are located in the community center building, not in the school. The TV and VCR in the schools are to be made available for community use in the evenings. Although TV antennas were provided in each village, broadcast TV reception is possible only in Donguila and Onguia-Bougandji at this time.

3.1.3 Water Systems

Each of the villages was provided with a water system consisting of a newly-drilled well, a water pump, a water tank and a water distribution system. The volumes of water required were based on an MERH estimated need of 15 liters/person/day and village population, and were estimated at:

- Donguila	5625 liters/day
- Nyali	6600 liters/day
- Onguia-Bougandji	12750 liters/day
- Bolossoville	21000 liters/day

The smaller villages (Donguila and Nyali) were each to have two (2) water fountains, while the larger villages (Onguia-Bougandji and Blossoville) were each to have three (3) water fountains. Each water fountain consists of an upright pedestal with two (2) spring return faucets.

As is typical with PV pumping systems, batteries were not used for storage. Instead, the array was coupled directly to the pump, and water was stored in large tanks. These tanks were sized to produce five days' supply of water to the villagers without additional pumping (i.e., five days' autonomy).

3.1.4 Village Light

Each of the villages was provided with one low-pressure sodium vapor street light. The street light was to automatically turn on at dusk, operate for six (6) hours, and then automatically turn off. This is the smallest system, and features modules mounted on top of the pole used to hold the light.

3.2 Donguila Installations

3.2.1 Water System

In order to provide adequate pressure to the water fountain located at the wellhead near the dispensary, a 20,000 liter (2 cubic meters) elevated vertical water tank was used. Two fountains were described in the design, one located 3 meters north of the water tank, the other about 562 meters southwest of the water tank near the church. During installation, a third fountain was added near the girl's dormitory. A survey by SEEG/MERH indicates that the fountain near the church is 12.1 meters below the wellhead. The pump PV array was located on a concrete pad immediately adjacent to the dispensary array and also immediately adjacent to the well.

The original array of 24 modules was not sufficient to provide for the village's water needs. In late January 1986, an additional sixteen (16) modules were added to the system, bringing the total number of modules to forty (40).

High-density polyethylene (HDPE) pipe was used in this village. The well casing is 7 inches in diameter.

3.2.2 Dispensary

The underground cable between the array and dispensary is 16.2 meters long and enters the dispensary on its west end. Building construction is concrete block. Switches were surface-mounted, using plastic inserts in 6 mm holes. Wire molds were used for all drops to switches. Lights were hung on short chains from eyehooks in the roof rafters. The fan was mounted to roof rafters. All horizontal wiring was placed in snap-open conduit mounted along the tops of walls. The refrigerator/freezer was placed in the consultation room.

3.2.3 School

The Donguila school is an old concrete block building containing four classrooms on the first floor and a boy's dormitory on the second floor. The building has wood slatted windows for ventilation and light. The TV and VCR are located in a lockable wood cabinet located in the center (largest) classroom. The 40-watt fluorescent lights were mounted using eyehooks and chains from holes in the ceiling. Wire mold was used for all interior wiring.

3.2.4 Village Light

The village light is located 30 meters east of the church in a large area also used as a playground for the school.

3.3 Bolossoville Installations

3.3.1 Water System

The well is located near the center of the village. The horizontal 30,000 liter water tank is located 190 meters northeast and about 3.6 meters higher than the wellhead and is equipped with a float switch. Three fountains are located along the main road requiring about 800 meters of pipe. One hundred meters of pipe was required to connect the tank to the road. The water line passes under the main road through the village. The fountains range from 6.1 to 13.7 meters below the level of the tank. The fountain near the school is 8.6 meters from the road. Per the agreement with the MERH, galvanized pipe was used.

3.3.2 Dispensary

The dispensary is constructed of concrete blocks and has an enclosed attic with access. Lights and the fan were mounted directly to the plywood ceiling. Switches and wire mold were mounted using plastic inserts. Wiring was run in the attic. Due to door size restrictions (68 cm), the R/F was installed in the examining room. The fan was also installed in the examining room. No light was placed in the left rear room. Wiring entry is at the southeast corner (examining room) of the building, with the array located 9.6 meters south and west of the building.

3.3.3 School

The school is constructed of concrete blocks with an open attic. Lights were hung from the beams with short chains and eyehooks. Switches were surface-mounted to the walls using plastic inserts in drilled holes. Wire mold was used for drops to the lights. The array is located behind the school about 9.2 meters west of the northwest corner of the school. There is no TV/ VCR in this school.

3.3.4 Village Light

The village light is located next to the fountain near the center of the village and along the main road going through the village.

3.3.5 Community Center

This building is constructed of an inner frame of approximately 5 cm diameter vertical poles woven with vines and then filled with mud. A cement stucco is applied on both sides as a finish coat. The building disconnect switch and the wall switches were placed on plywood plates approximately 30 cm square and mounted with through-bolts. The ceiling is bamboo and requires wire mold for wiring, as attic access was impractical. The TV and VCR were installed in an enclosed floor-mounted security cabinet. The array is located about 9.5 meters east of the community building.

3.4 Onguia-Bougandji Installations

3.4.1 Water System

The well is located just above the floor of a valley southeast of the village. A road going past the well is in the process of being improved and will become the main road to Akieni. The array is located about 30 meters up the hill from the well for better sun exposure.

The tank was placed next to another road at the high point of the village. The tank is 33.86 meters above and 600 meters from the well. Galvanized pipe and a horizontal tank of 20,000 litres were used. The minimum drop from the tank to any fountain is 7.35 meters. Three fountains were required, but four were installed, one of them at the request of the village chief during installation.

3.4.2 Dispensary

The dispensary is a pole/vine/mud building similar to the Bolossoville community building and required mounting plates for switches. The villagers enlarged the door on the northwest corner so that the R/F could be installed there. The array is about 3 meters east of the building and is connected to the building by a 3 meter aerial cable. Since the build ing floor is dirt, a 1m x 2m concrete pad was provided for the R/F.

3.4.3 School

The school was constructed by the U.S. Peace Corps of concrete block and has an enclosed attic. Switches were surface-mounted with plastic inserts in 6 mm holes. Wire mold was used on walls and ceilings. The lights were mounted directly on the plywood ceiling. The array is located at the edge of a field, 29 meters northwest of the school.

3.4.4 Village Light

The village light is located on the southeast corner of the intersection of the two roadways passing through the village.

3.5 Nyali Installations

3.5.1 Water System

The well is located next to the main road across from the rice paddies. The array was placed next to the well. The water tank was located about 180 meters up the hill to provide adequate water pressure for the most distant fountains. The three water fountains were installed; one at the well, another 500 meters ourth of the well, and a third 612 meters south of the well.

3.5.2 Dispensary

This building is also constructed with mud walls but is carefully finished with stucco. Switches and disconnect required plywood mounting plates and through wall bolts. The fan was mounted directly to a roof beam. The lights were installed on chains hung from roof beams. The array is behind the building connected to the building by a 12 meter aerial cable for connection. The refrigerator/freezer was placed in the southeast corner of the building.

3.5.3 School

The system for the Nyali school was not installed since the existing school was judged by MERH to be inadequate from a structural standpoint.

3.5.4 Village Light

The village light is located in front of the village chief's house.

Section 4. SUBSYSTEM AND COMPONENT DESIGN REQUIREMENTS AND DESCRIPTIONS

4.1 Power Subsystems

The power subsystem consists of those components that provide the electrical power and includes array, instruments/controls, and batteries.

4.1.1 Array Subsystems

For systems other than the village light, a building block approach for the array was adopted. This consists of an array structure, battery enclosure, fence and instrumentation/control assembly designed as an integrated structure (see drawing 01DSB28095B in Appendix A).

a) Modules

The basic photovoltaic system building block is the Solavolt MSP43E40 Photovoltaic Module. This module produces 40 watts at nominal operating conditions and is designed to charge a 12 volt storage battery. These modules are JPL Block IV qualified and had been in production at Solavolt for over four (4) years. The module is described in more detail in Appendix B.

For the pumping systems, a special high-voltage system module (MSP43E40B) containing integral bypass diodes across every 11 solar cells was used. The diodes eliminate any chance of hot spot damage that could result from operating a high voltage branch circuit under short circuit conditions.

b) Structure

The modules are mounted on an aluminum array structure that elevates the modules to 7-8 feet above ground and which tilts the modules to the north. The square columns that support the array structure also serve as fence posts for the chain link fence that surrounds the array. The fence has a gate to permit access under the array. The array structure was mounted on a concrete foundation by use of anchor bolts that were installed after the concrete had set. This was done to provide for higher precision in the placement of the mounting bolts.

4.1.2 Battery Subsystem

The batteries for dispensaries, schools and the community center are contained in molded, vented and locked battery enclosures (see drawing 16CSB28109B, Appendix A). The battery enclosures are located on the concrete pads under the arrays. Circuit breakers rated at 35-50 amps are located on the instrument enclosures for any normal or emergency protection, placing any sparking away from the batteries.

The batteries are composed of ESB Wisco model DH-5-1 2 volt battery cells. This is an older design cell that has proved to be very reliable in PV systems. The grids in this design are of pure virgin lead and enable the battery to have a very low self-discharge rate (1% per month).

The use of electrolyte fill caps enables the cell to be serviced annually. Appendix B contains data on this cell that includes:

a) Ampere-hour capacity vs. temperature
b) Ampere-hour capacity vs. discharge rate
c) Freezing point vs. specific gravity (can calculate vs DOD)
d) Self-discharge rate at 80 deg. F
e) Open circuit voltage vs. depth of discharge
f) Specific gravity vs. depth of discharge.

Cell capacity is rated at 600 ampere-hours at the intended discharge rate. For 12-volt systems, 6 cells are used in series. Dispensary systems use 24 cells (our series strings); schools with TV/VCR use 18 cells (three series strings); the Bolossoville school (with TV/VCR) uses 12 cells; and the Bolossoville community building uses 18 cells.

Seven (7) years of prior experience in the field with PV systems have shown no battery failures due to aging of the batteries. Batteries removed from extended service have exhibited little grid corrosion in a laboratory analysis by the manufacturer. Since no upper service temperatures are defined for this family of batteries, the expected temperatures in Gabon are well within the normal service range for this battery. For the intended use of these batteries in systems with low voltage protection and moderate ambient temperatures, a service life of at least 10 years is anticipated. A supply of distilled water for replenishment of the electrolyte for two (2) years was provided at installation and then replenished the close of the contract. water is in containers marked in French and English and stored in the battery enclosures.

Each array enclosure is provided with an emergency eyewash apparatus mounted on the inside of the fence next to the battery enclosure. Each battery system using DH-5-1 batteries was provided with an apron and gloves for use by maintenance personnel when maintaining the batteries.

4.1.3 Instrument/Control Subsystem

The instrument/control subsystems contain all of the instruments and controls required for operation of the power subsystems.

The instruments and controls for each system are mounted in an aluminum enclosure. The enclosure is located on the array support structure and is accessible from both inside and outside the fenced area. The enclosure has doors on both the front and rear for easy access to all wiring. One of the front doors has a window for viewing all instruments from which routine data must be recorded (see drawings 01DSB28084B and 79ESB28086B, Appendix A for an example). A system emergency shutoff switch is located on the side of the enclosure where it is accessible from both inside and outside the fenced area.

The basic interconnection of the controls and instrumentation is shown in Figure 4-1 for all systems that include batteries. The required controls and instrumentation varies with the type of system:

INSTRUMENT	DISPENSARY	SCHOOL	COMMUNITY CENTER	WATER	VILLAGE LIGHT
Array Branch Meters	4	3	3	3-7	1
Voltage Regulator	4	3	3		1
PV System Instrumentation	1	1	1	1	1
High Voltage Disconnect	1	1	1		1
Low Voltage Disconnect	1	1	1		1
Low Voltage Load Shedding	1				
Circuit Breakers	1	1	1		1
Alarm	1	1	1		1
Insolometer		1			
Fan Runtime Meter	1				
R/F Instrument	1				
R/F Runtime Meter	1				
Water Meter				1	
Pump Runtime Meter				1	

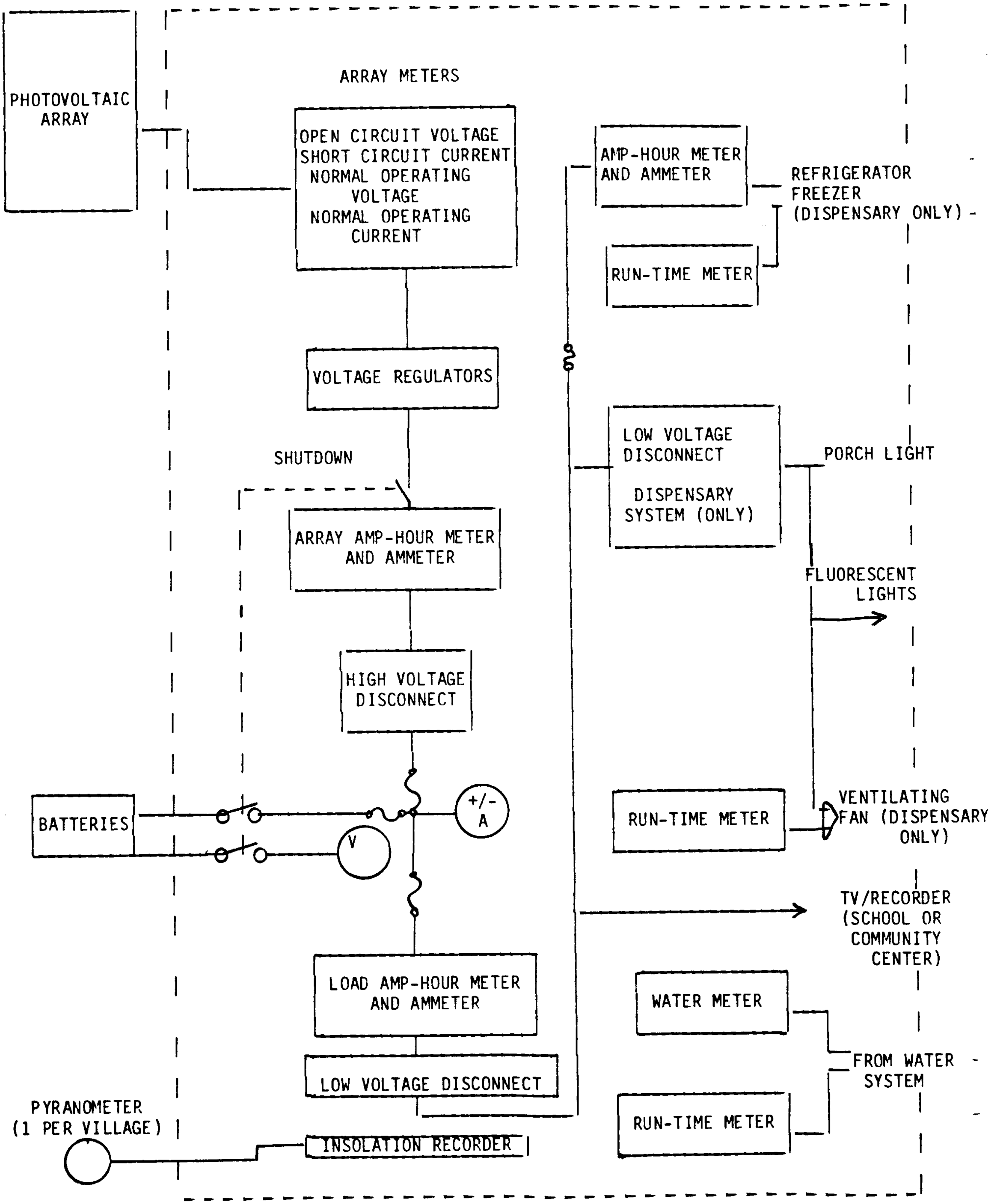


FIGURE 4-1. INSTRUMENTATION DIAGRAM

The instrumentation in the enclosures consists of:

a. Array branch meters to measure open circuit voltage, short circuit current and normal operation voltage and current for each branch circuit in the array. The array branch meters are custom versions of the Specialty Concepts Inc. "meter box" (Appendix B) that include a special Solavolt-developed three-position toggle switch. This switch is spring-loaded to its center position for normal operation of the array branch circuit of 2 to 5 modules. The left position disconnects the branch circuit from the voltage regulators and then shorts the branch circuit so that the short circuit current can be measured. The right position disconnects but does not short the branch circuit so that open circuit voltage can be measured. The voltmeters for the 12-volt systems have a 10 to 25 volt range while the meters for the pump systems have a 0 to 100 volt range. The dispensary, school and the community building systems' ammeters have a 0 to 15 amp range, the pump system array meter has a 0 to 10 amp range, and the village light array meter has a 0 to 5 amp range.

b. The voltage regulators are designed and manufactured by Specialty Concepts Inc. and sold by Solavolt as model MSR12S10 (Appendix B). This regulator incorporates the following special features:

   - No external temperature probe
   - Circuit board coated with acrylic coating for tropical use
   - 15-amp fuse in the array positive input lead
   - Light Emitting Diode (LED) to indicate charging
   - Labeling in French

c. PV System Instrumentation - This is a dual channel Curtis Instruments Inc. monitor and integrator that measures and displays the following on separate meters or counters:

   - Array ampere-hours
   - Array current
   - Load ampere-hours
   - Load current
   - Battery current (0-75 Amps)
   - Voltage (10-20 volts, or 0-100 volts)

d. High and Low Voltage Disconnects - These are modified Specialty Concepts Inc. "Battery Savers" (Appendix B) that ensure system safety by disconnecting the array if the battery voltage exceeds 16.5 volts and disconnecting the loads if battery voltage falls below 11.0 volts. These are designed to disconnect currents up to 30 amps and are equipped with a second single pole double throw (SPDT) set of contacts on the relay to activate the alarm system. The dispensary systems also have an additional low voltage cut-off that is used in a load-shedding mode to preserve R/F operation under conditions of abnormally-low battery state-of-charge. It disconnects both the lights and fan if the battery voltage falls below 11.7 volts.

e. Circuit Breakers - The Heinemann series AM circuit breaker was selected for its moisture and fungus resistance and the availabilty of auxiliary SPDT contacts required by the alarm system. Circuit breakers are used to protect the array, battery and loads.

f. Alarm - This is a custom circuit that monitors the status of the circuit breakers and high/low voltage disconnects. The outputs are three (3) LED's that indicate system voltage as being "LOW", "NORMAL", or "HIGH" and an audible alarm that is activated by a circuit breaker that is tripped or by either a high- or low-voltage disconnect. The alarm sounds until the condition is manually reset.

g. Insolometer - Insolation is measured and recorded by a Li-Cor LI-200 SD silicon cell pryanometer and a single channel Curtis Instruments monitor/integrator. The output of the pyranometer is set for 10 millivolts at an irradiance of 100 milliwatts per square centimeter (full sun). Instantaneous irradiance is displayed on an analog meter and the <u>integral of the irradiance</u> (insolation) is displayed on a mechanical counter. The insolometer for each village is attached to the school system array and the instrumentation is located in the school system instrumentation enclosure.

h. Refrigerator/Freezer (R/F) Instrumentation - A single channel Curtis Instruments Inc. monitor/integrator measures and displays actual operating voltage and current of the R/F and integrated current. A separate quartz movement clock timer is used to measure compressor runtime. The runtime meter is connected to the fan output of the electronic module that operates the compressor. The fan is designed to operate only when the compressor is operating.

i. Water Meter - The amount of water pumped is measured by an electro-mechanical counter that indicates the flow in cubic meters. The water meter requires no external power to operate the counter and may be read at the wellhead. It also has an electro-mechanical meter located in the pump system instrumentation enclosure.

4.1.4 Power Distribution

Power distribution from the array to the buildings (school, dispensary, etc.) is through type USE direct-burial rated cable. The cable was routed through short lengths of PVC conduit from the instrument enclosure, over the concrete pad and into the ground, and from ground up to the building-mounted disconnect switch. The dispensary systems in Onguia-Bougandji and Nyali used aerial cables due to the short distance at Onguia-Bougandji and a concrete foundation extension at Nyali. The dispensary systems use a four (4) conductor power cable plus a four (4) conductor instrumentation cable while the other systems require only two (2) conductor cables. The dispensary systems are different due to the need to separately power the R/F and to monitor the R/F current, voltage, ampere-hours, and compressor run-time.

The power cables from arrays to the buildings terminate at disconnect switches on the outside of the buildings.

Wiring within the buildings uses type THHN wire of #2 or #4 gauge installed at the top of the walls for the major power distribution. Connections to switches and loads are in 10/2 tray cable. Drops to switches and cables to ceiling mounted lights are enclosed in wire-mold. Details of each installation are given on the site plans.

4.2 System Design

Solavolt's contract with NASA required that the systems be designed to meet the following load availability requirements:

LOAD AVAILABILITY REQUIREMENTS

SYSTEM	LOAD	MONTHLY AVAILABILITY
a) Dispensary Systems:	Refrigerator/Freezer	99% or greater
	Lights	95% or greater
	Ventilation Fan	90% or greater
b) Education or Community	Lights	95% or greater
	Audio-Visual Equip.	95% or greater
c) Potable Water	Pump & Storage	95% or greater of the design water requirements
d) Outdoor Light	Light	90% or greater

4.2.1 12 Volt D.C. Systems

The Solavolt Solar Sizing Program was used to calculate the optimum system configuration for the 12-volt DC systems used for the dispensary, school, community center, and village light systems. The Solavolt Sizing program containing weather data for over 1300 world-wide locations stored in the form of monthly average global insolation for 13 tilt angles for each location. For this project, a special file was created containing insolation values extracted from information supplied by NASA (see Reference 1).

For each tilt angle there is an optimum system configuration which has the lowest cost trade-off combination of PV array size and battery capacity. The program calculates the cost of modules plus batteries, for each case, and finds the five configurations with the lowest cost.

The required inputs to the sizing program are:

a. The system nominal voltage

b. The daily average load in amp-hours per day

c. Insolation and other weather data for the site

d. Minimum and maximum ambient temperatures expected

e. Additional battery capacity required based on the number of days of consecutive bad weather (effectively sunless days) estimated for each site.

During the optimization cycle, the program steps through 13 tilt angles, for site latitude +/- 30°, in steps of five degrees. This ensures that the angle selected will be within three degrees of the optimum tilt angle. For each of these tilt angles, the output (amp-hrs) to be expected from one module, or single series string of modules, is calculated for each month. Given this data, the minimum number of modules (rounded up to the next whole number) required to meet the annual load requirements is calculated. With this particular configuration, some months will yield more output from the array than the load requires. Other months may result in a array output deficit. The program calculates the worst annual accumulated deficit, and from this deficit, is able to calculate the battery capacity required to offset this deficit. The combined cost of this minimum array with maximum battery capacity is then calculated and remembered.

The program next calculates the battery capacity required as the array size is progressively increased, one module (or series string) at a time. The new combined cost is compared in each case with the previous combined costs. This process is repeated for each tilt angle and the five lowest cost systems are recorded. The most suitable of these configurations (from a cost-effectivity and reliability viewpoint) is selected by the operator.

The program then prints out the details of the selected configuration, and also calculates and prints out the expected annual performance of the system for each month of the year. This performance table includes:

a. The horizontal global insolation data on which the calculations were based

b. The calculated global insolation on the array

c. The calculated array output in amp-hours per day

d. The load in amp-hours per day

e. The array/load safety factor percentage, i.e., the ratio of calculated array output to expected load

f. If 'seasonal' battery capacity is required, an additional column is added showing the system/load safety factor percentage. The system output is defined as the array output for the month plus the available battery capacity at the beginning of the month.

The program also calculates the battery capacity required for 'sunless days.' This battery capacity is independent of the 'seasonal' battery capacity and is not included in item (f) above. It is based only on the daily load requirements and the number of 'sunless days' specified.

Seasonal and sunless days battery requirements are added together before calculating the optimum battery configuration which will meet the combined requirements. In addition, the effect of ambient temperature on the available capacity of the batteries is taken into account.

The program then prints a second page which gives a breakdown of the individual components that make up the system and their respective costs. This breakdown includes:

a. Module type

b. Array configuration (number of moduels, required tilt)

c. Number and type of regulators required

d. Support structure and wiring harness

e. Batteries required (rounded up to the next whole number)

f. Total system cost.

The size of each of the 12-volt systems (i.e., all systems except the pumping systems) was determined using the expected system load as experienced in ampere-hours per day. The ampere-hour per day values were then used with the Solavolt system sizing program to determine the array design. A summary of the system load devices is shown below. The resulting computer sizing for each system are contained in Appendix C.

Summary of System Loads

System	Load Device	No.	Amps Each	hr/day	amp-hr/ day
Dispensary	R/F	1	1.66	24	40.0
	Fluorescent Light 40W	4	3.0	4	48.0
	Fan	1	1.0	4	4.0
	Porch Light (LPS)	1	2.3	4	9.2
	Instruments	1	0.5	24	12.0
					113.2
School (ex. Bolossoville)	Fluorescent Light 40W	9	3.0	2	54.0
	TV	1	4.0	4	16.0
	VCR	1	1.0	2	2.0
	Instruments	1	0.5	24	12.0
					84.0
Outdoor Light	18W LPS	1	2.3	5	11.5
	Instruments	1	.15	24	3.6
					15.1
Bolossoville Community Center	Fluorescent Light 40W	4	3.0	4	48.0
	TV	1	4.0	4	16.0
	VCR	1	1.0	2	2.0
	Instruments	1	.33	24	8.0
					74.0
Bolossoville School	Fluorescent Light 40W	9	3.0	2	54.0
	Instruments	1	0.33	24	8.0
					62.0

The lowest cost system sizes established by the computer sizing program are summarized below:

Summary of System Sizes

System	Peak Watts Required	Modules	Battery Capacity (Amp-Hours)
Dispensary	640	16	2400
School (ex. Bolossoville)	560	14	1800
Outdoor Light	80	2	210
Bolossoville Community Center	560	14	1800
Bolossoville School	320	8	1200

4.2.2 Sizing of Water Pumps

The water systems use Jacuzzi DC water pumps. These pumps feature a submersible design with a SJ1 brush-type DC motor directly coupled to a model C14 centrifugal pump. The sizing of an array to directly operate this pump is a complex procedure with part of the calculations requiring numerous iterations to determine the optimum operating voltage and current.

The pumping requirements for each village are:

Village	Static Head Plus Tank Elevation (M)	Water Requirements (m^3/Day)
Donguila	43	5.6
Nyali	20	6.6
Onguia	65	12.7
Bolossoville	89	21.0

Hourly insolation data used for water pump sizing and performance evaluation is based on data taken by Solavolt personnel at an installation in Kougouleu, Gabon during evaluation of an earlier Solavolt system there. Kougouleu is about 40 km from Donguila. This data is presented below in terms of monthly averaged daily sunhours (kwh/m^2) on the array with a tilt angle of 10° facing North.

MONTH:	JAN	FEB	MAR	APR	MAY	JUN
INSOLATION:	3.78	3.90	4.00	4.77	4.47	4.00
MONTH:	JUL	AUG	SEP	OCT	NOV	DEC
INSOLATION:	3.20	3.31	3.95	3.37	3.04	3.78

AVERAGE: 3.86

Since a constant minimum daily volume of water is required for each of these villages, performance estimates were made based on worst month (July) performance. The 3.20 sunhours (kwh/m^2) sunhours isolation expected on a July day was assumed to follow a smooth curve throughout the day. The ambient temperature was assumed to be 32°C. The irradiance for every half-hour interval of the day was determined and used in the calculations.

The sizing process starts by considering the voltage, pump motor requirements, etc. to determine the array size and configuration, e.g., 24 modules wired in eight parallel strings each with three series modules.

A computer program is used to size the various systems. The program calculates the current-voltage (I-V) curve of a module for the irradiance level on the array and the ambient temperature for each half-hour increment from dawn to dusk. The I-V curve voltages are then scaled by the number of series modules and the currents are scaled by the number of parallel strings to obtain an array I-V characteristic.

Prior to the sizing, the flow and head (pressure) characteristics of the pump/motor combination are measured at various voltages and currents. From this measured data and a series of general pump performance equations, it is possible to calculate the voltage and current needed to produce various flow rates at various total dynamic heads (pressures) for each system. Several pump designs were analyzed and the Jacuzzi SJ1/C14 combination was determined to be the best choice for all villages.

The primary task of the computer program is to search iteratively for the intersection point of the array and pump IV curves. This is the operation point of the pump/motor/array system under the particular irradiance/ temperature/dynamic head conditions. Wiring losses in the system were modeled by assuming a linear voltage drop with array current.

Algorithms are used to model hydraulic system losses (friction and water level drawdown) as a function of flow rate. In order to do this, it is necessary to assume a flow rate and execute a binary search to find the correct dynamic losses for each operating point.

This procedure is repeated for half hour intervals throughout the day and the daily total numerically integrated flow is determined. If the required volume is not pumped, the array size must be changed and the process repeated.

This procedure was followed for each village. Test data for the Bolossoville well indicated that the well would not yield the required 21 cubic meters per day; therefore, a pump design was developed based on the measured yield of that well. The resulting designs were:

Village	Number of Series Modules	Number of Parallel Strings	Worst Month Daily Flow (m^3)*
Donguila	3	8	4.5
Nyali	3	6	5.4
Onguia	4	12	8.5
Bolossoville	4	20	9.7

*month of lowest insolation

Since the design was made for cloudy conditions, it was necessary to check that the pump motor will not exceed its maximum ratings of 60 volts and 20 amperes on bright sun days thus contributing to possible pump failure. Since the Bolossoville pump was the only one close to operating at the maximum ratings, it was decided to use a pump motor (model SJ2) with a heavy-duty magnetic clutch to avoid any possible problems under full-sun conditions for the village. This clutch decouples the motor from the pump under high array current levels. The spare pump, left with the MERH, also has an SJ2 motor and can be used in any of the villages. Limited initial availability of SJ2 motors during system procurement precluded their use in all villages.

4.3 Systems Installation Descriptions

4.3.1 Dispensary Systems

The dispensary systems each use a 16-module 40-watt array. A typical dispensary site plan is included in Appendix A (drawing 79CSB28052B) and shows the usual arrangement of subsystems and details of how the load devices are installed. Appendix A contains a typical wiring diagram (drawing 69CSB28053B) and the corresponding schematic (drawing 63DSB28083B). The instruments and controls are as shown on the Dispensary System - PV System Instruments and Controls Layout (drawing 79ESB28086B).

The dispensary PV systems should power all loads for all seasons for the specified number of hours per day. If usage exceeds specifications and/or there is less sun than expected, battery state-of-charge and system voltage will decrease. If battery voltage drops below 11.5 volts, a low voltage disconnect is designed to disconnect the fan and lights so that the remaining energy is fully available to the refrigerator/freezer. This load shedding is automatic and does not sound any alarm. Normal operation of lights and fan is restored when battery voltage recovers to 12.8 volts. If system voltage falls below 10.5 volts, the R/F is disconnected and an alarm sounds. The R/F is reconnected when the system voltage reaches 12.5 volts.

Figure 4-2 is a sketch of a typical dispensary system.

4.3.2 School and Community Building Systems

The school and community building systems use the same general design approach as the dispensary systems. The major differences are a reduction in modules to 14 from 16, and a reduction in battery cells to 18 from 24. The loads consist of lights and a TV/VCR. The instrumentation includes equipment for measuring insolation. Not all of the schools are the same, however. In Bolossoville the school does not have the TV/VCR and as a result requires a smaller array structure. Only the village of Bolossoville has a community building and this building contains the TV/VCR and lights. These systems do not use any load shedding as there are no priority loads.

An attempt was made to locate the array subsystem for the schools away from play areas. A typical school site plan is included in Appendix A (drawing 79CSB28057B) and shows the usual arrangement of subsystems and details of how the lights and TV/VCR are installed. Figure 4-3 shows a typical school system.

4.3.3 Water Systems

The water systems are different from the school and dispensary systems in that they do not use batteries. Instead of using energy storage, the pumping systems use product storage (water) by pumping water into a large tank. The pumps operate when the solar irradiance is over a minimum level, typically 30 to 40 mw/cm^2. The tanks and pumps are large enough to ensure adequate water under normal conditions.

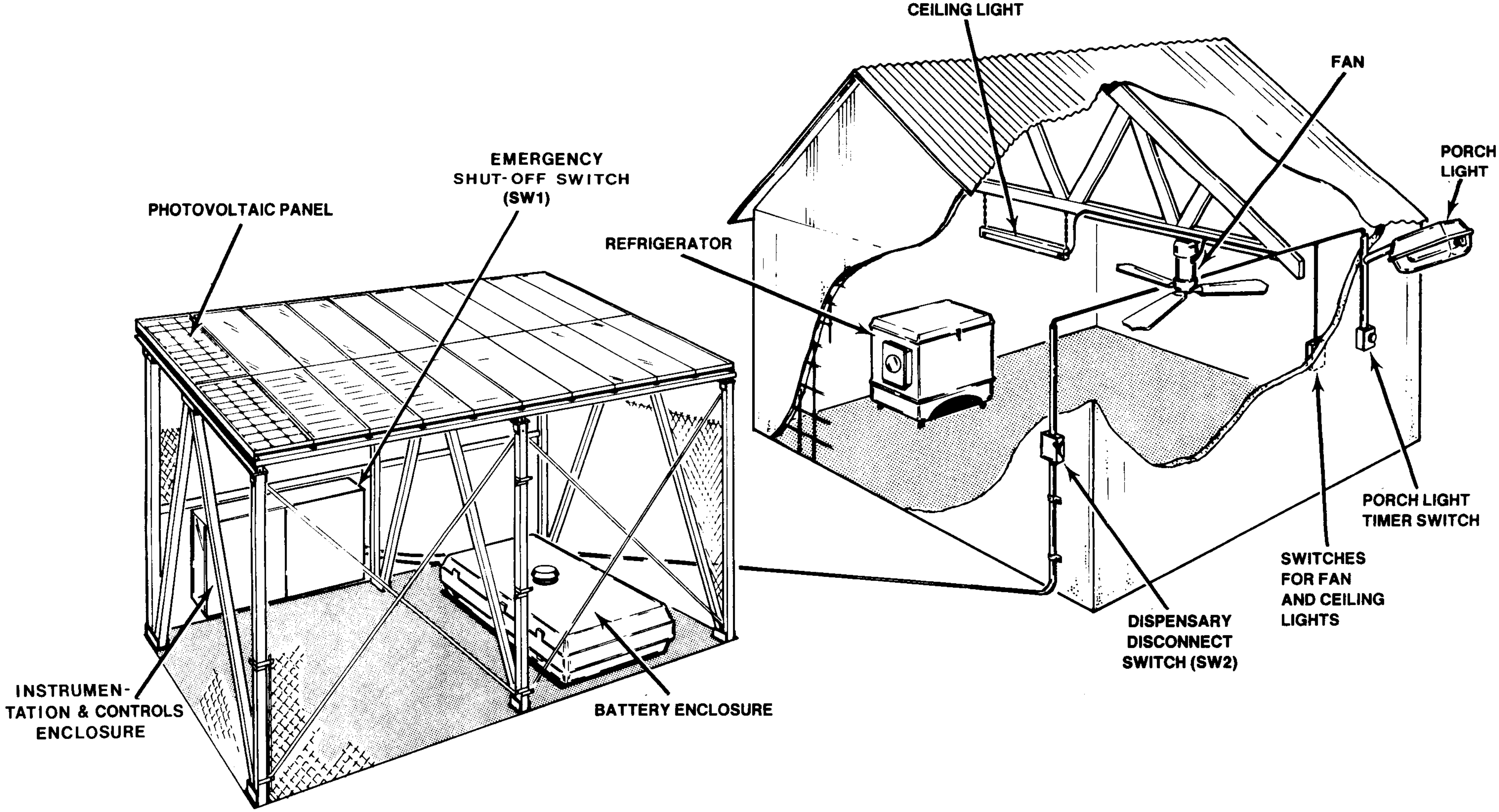


Figure 4-2. Village Dispensary Photovoltaic Power System

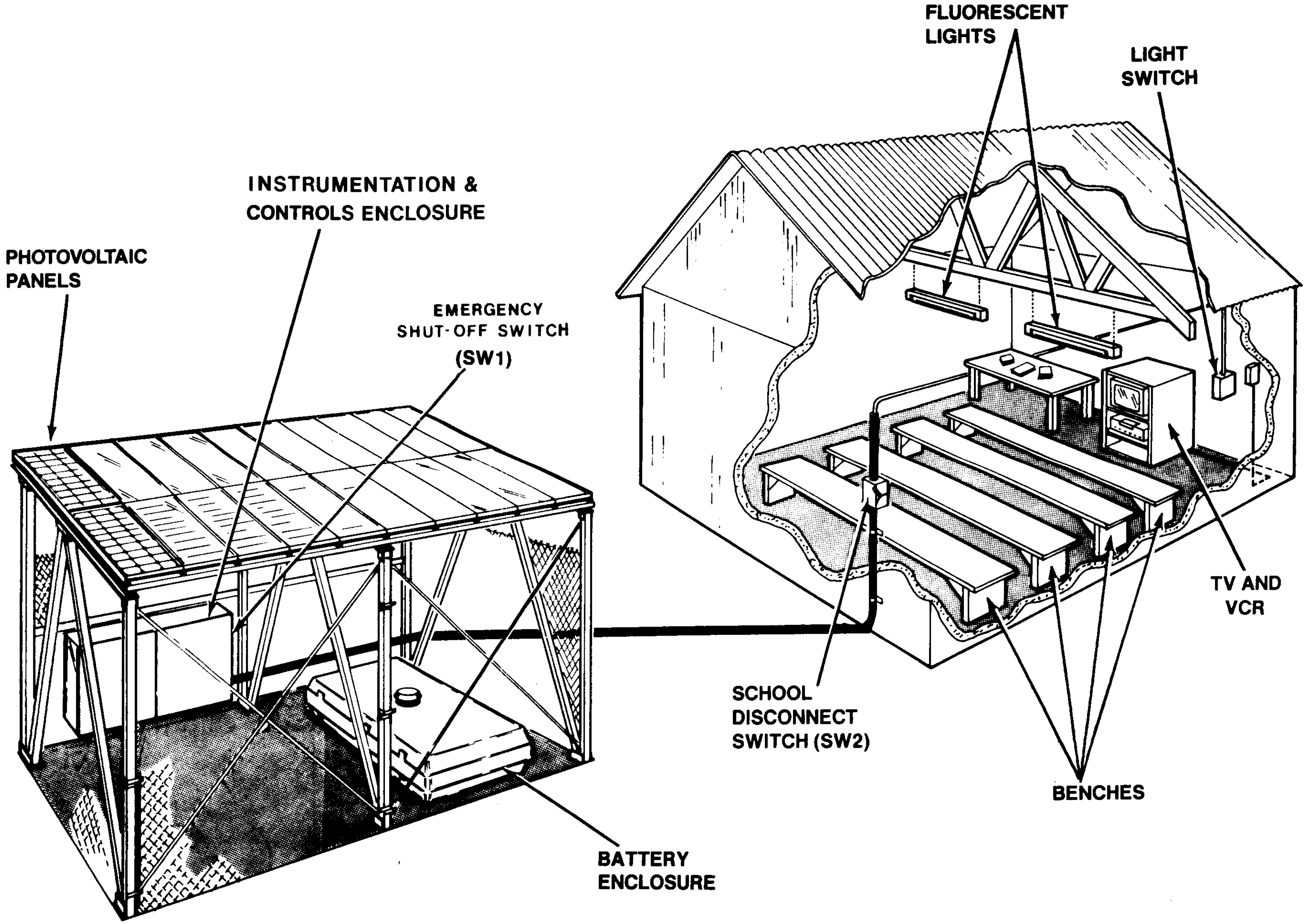


Figure 4-3. Village School Photovoltaic Power System

4.3.3.1 Water Pump

The water pump is a submersible unit with a sealed brush-type DC motor. The motor is designed to operate directly from the array without any additional components. This type of operation is expected to be very reliable as there are very few parts that can fail or that require maintenance. The only maintenance requirement is for the motor brushes which will require periodic replacement. The brushes should last at least 5 years in the pump that is operated at the highest power level (Bolossoville) and should last 10 years in the other villages. Brush replacement requires removal of the pump from the well. The pump and pipe can be removed from the wells by hand using a tripod left in each village and a pulley and winch left with MERH/SEEG. Spare brushes and instructions on how to remove the pump, replace the brushes and replace the pump have also been left with MERH/SEEG.

4.3.3.2 Instrument/Control Subsystem

Section 4.1.3 detailed systems instruments/controls. The instrumentation and controls for the water systems are simpler than for the other systems due to the absence of batteries. The voltage, current, ampere-hours and pump run-time are displayed in the instrument and control enclosure. The run-time meter for the water pump operates at or above voltages which result in water being pumped into the tank. The only control is a solenoid to disconnect the pump when a float switch on the water tank detects that the tank is full. A water meter calibrated in cubic meters is used to record the water pumped from the well. For ease of data collection, this water meter has a remote electro-mechanical meter that is located on the main instrument panel in the instrument enclosure.

The number of modules used for each water system depends on the depth-to-water, tank height and water requirements for the village. The Donguila and Nyali arrays have three modules in series while Bolossoville and Onguia-Bougandji arrays have four modules in series.

4.3.3.3 Water Storage Subsystems

The water tanks were installed at the high point of each village. In Donguila, an elevated 20 cubic meter tank is used because pressure to operate a water fountain is required right at the tank. The other villages use 20 or 30 cubic meter skid mounted horizontal water tanks. The water tanks were the single most expensive item in the project. Transportation of the water tanks to the villages was very difficult because the expected dry season during the summer of 1984 did not occur and the roads were very difficult to travel.

The water tank at Donguila has a pressure gauge calibrated to show water level. The water tanks at the other three (3) villages were provided with a clear plastic pipe as a sight gauge for water height. This clear plastic pipe was not installed because of MERH concern that children would damage it.

4.3.3.4 Water Distribution Subsystem

The villages of Donguila and Bolossoville use two-inch diameter high density polyethelyene (HDPE) water pipe for the distribution system. The other villages use two inch diameter galvanized steel pipe. The two types of pipe were used to determine which was preferred for future systems.

For the HDPE pipe, Solavolt used a 200 psi heavy wall pipe with pack joint type fittings for connections. The HDPE is preferred from an installation point of view as it is much easier to install due to lower labor requirements, no requirement for straight trenches, and ability to make turns without fittings. Questions about durability were answered during installation in Donguila when a heavy truck fell into the loosely packed dirt in a trench on two occasions and got the wheels mired in mud (due to rain) down to the depth of the pipe (80 cm) and did not damage the HDPE pipe. HDPE pipe is used in all wells for ease of installation.

Water is available for the people of the villages at 2 to 4 water fountains per village. Each water fountain consists of two spring return water faucets mounted on a heavy pipe extending up through a concrete pad. Water is not provided inside of any buildings.

The water distribution subsystem (see drawing 79CSB28012B in Appendix A for an example) includes all necessary valves, check valves, and other fittings in addition to the pipe. Provisions have been made for extending the distribution systems in the future. It should be noted that while all plumbing parts are standard U.S. items, the European plumbing parts used in Gabon have the same threads and can be interchanged. Copper tube sizes are different from the U.S. sizes but none was used in this project.

4.3.3.5 Water Tanks

The water tanks were fabricated in Gabon from steel to standard Gabon designs for horizontal and vertical water tanks. A Gabonese Department of Health approved epoxy coating system was used to prevent corrosion. During the pre-design site visit, it was determined that horizontal skid mounted water tanks could be used in Nyali, Bolossoville and Onguia-Bougandji.

The water tanks are equipped with float-type level switches to shut off the water pump when the tanks are full. The tanks are also equipped with access covers, as well as internal and external ladders, so that they may be easily cleaned.

Drawing: Water tank 79CSB28100B (Appendix A).

4.3.3.6 Water Pipe

As mentioned earlier, Donguila and Bolossoville have HDPE pipe for the distribution system while Onguia-Bougandji and Nyali use galvanized steel pipe. All distribution pipe is 2-inch nominal pipe size. This size was chosen to minimize pressure drop due to flow over the long distances in the villages. Smaller pipe would have required either elevated tanks or auxiliary pumping systems. Only one size of pipe was used to minimize design and supply problems. All required piping fixtures were supplied from the U.S. as complete kits. Solavolt designed and provided a simple water distribution fountain, constructed mostly of 2-inch pipe, to replace a rather expensive French "Borne" fountain in general use in Gabon. See Section 5.3.4 for greater detail. Each water system includes a water meter to measure the water pumped and a check valve to prevent water from draining back down into the well when the pump is off.

Drawing:	Donguila Water System Distribution Plan	79CSB28012B	(Appendix A).
	Water System Fountain Assembly	81BSB28099B	(Appendix A).

4.3.4 Village Light System

Each village was provided with one (1) 12-volt, 18-watt low pressure sodium (LPS) street light that has a darkness sensor and an automatic timer. This is a self-contained system. The timer and light are turned on at dusk. The timers are set for four (4) hours, after which the lights are shut off. The timers are easily field-resettable; and if actual insolation data indicates longer lamp run-times can be supported, the run-time (and timer) can be adjusted for longer periods of lamp operation. During the Final Inspection Test, the timers for the village lights in Donguila, Bolossoville and Nyali were reset for 6-hour operation after a on-site review of the insolation and performance data.

The basic parts of the village light system are:

o Custom galvanized steel pole with integral top array mount

o 2 MSP43E40 modules

o 2 Delco 2000 PV batteries in a lockable battery enclosure and on instrumentation and control enclosure containing:

- PV system instrumentation
- Array meter (1)
- Voltage regulator (1)
- Array/load ammeter and ampere-hour meters
- High and low voltage disconnects
- Alarm monitor

o 12-volt, 18 watt REC Specialities LPS lamp fixture with:

- Built-in field resetable timer
- Darkness sensor.

Drawing number 01CSB28101B in Appendix A shows the assembly of this light system. Low pressure sodium lights are used because (1) they are more efficient than other types of lights; and (2) they do not attract as many insects as do other types of lights.

4.4 Electrical Load Devices

The requirements for types and numbers of load devices are listed in Section 2. A description of the load devices supplied is as follows:

4.4.1 Fluorescent Lights

The fluorescent lights supplied for the dispensary, schools and community building are single lamp 40 watt 12 volt fixtures with built-in inverters for 12-volt operation. They are manufactured by REC Specialities (See Appendix B). Each lamp has been fitted with a clear Lexan shield and end caps to fully contain all pieces in the event of breakage. The covered lamp is fully exposed, since enclosed fixtures are not desired in Gabon as they tend to fill up with insects. The fluorescent lamp assemblies are either ceiling-mounted or hung by short chains from open rafters, depending on the building's construction.

4.4.2 Ceiling Fans

The ceiling fans are "Casablanca" type 3-blade 12-volt fans that require one (1) amp to operate. They are controlled by solid state timer switches (See Appendix B). The timer switches were removed during the FIT visit because they proved to be unnecessary.

4.4.3 Porch Light

The porch light is a 12-volt, 18-watt low pressure sodium (LPS) light fixture from REC Specialities. It is controlled by a timer switch located outside the building on the porch set for a one (1) hour runtime. The timer switch is the same type discussed in 4.4.2.

4.4.4 Medical Refrigerator/Freezer (R/F)

The R/F is a top-loading 12-volt high efficiency unit manufactured by Marvel Division of Dayton-Walther Corporation. The model 4RTD was qualified by Solavolt International as meeting World Health Organization requirements for vaccine "cold chain" applications. This R/F is sold by Solavolt as model MSF100. The R/F is equipped with a 3-pen, 7-day mechanical clock driven temperature recorder that will record ambient, refrigerator and freezer temperatures on a 10 inch diameter temperature chart (See Appendix B). A four (4) conductor cable connects the R/F to the system instrumentation and controls enclosure so that the compressor runtime and actual R/F operating voltage can be monitored. Further details of the R/F are contained in Appendix B.

4.4.5 TV and VCR

Four (4) 42-cm color televisions (TVs) of suitable multistandard design and suitable VCR's (See Appendix B) were purchased in France for use in the schools and community buildings. It was necessary to purchase the TVs and the VCRs in France so that they would be compatible with the local TV standards. Both the TV and VCR are designed for 12-volt operation.

The TVs and VCRs are housed in plywood enclosures. The enclosures for locations other than Onguia-Bougandji are constructed with both front and read doors so that they could be placed in a wall for public use outside the school.

4.4.6 Village Light

The requirement for the outdoor area (village) lights was to furnish a low pressure sodium lamp of less than 30 watts that is enclosed in a weatherproof exterior fixture, and mounted on a suitable pole approximately 12 to 18 feet above ground.

The light used is a 12-volt, 18-watt LPS light fixture from REC Specialties that is equipped with an integral darkness sensor and timer. The systems were designed and sized for six-hour operation; however, MERH preferred to set the timer for four (4) hours at the time of installation.

Drawing: Village Light System-PV System Assembly 01CSB28101B (Appendix B).

4.5 Other System Requirements

4.5.1 Operating Environment

All electrical circuit boards were required to be conformally coated with a type AR or ER product per QPL-46058-23 in order to provide resistance to moisture and fungus.

The systems were designed and constructed to operate properly under the following environmental conditions:

a. Ambient temperatures between 10°C and 43°C.

b. Prevailing wind speeds up to 40 km/hr from any direction.

c. Wind gusts to 100 km/hr from any direction.

d. Dust, moisture, mild salt fog and fungus: Components, materials, assembly designs and enclosures were to be chosen to be resistant to dust, moisture, fungus and mild salt fog (but not insets!).

In addition to meeting the above requirements, Ceca Gadis noted that the instrument/control enclosures must be properly vented to avoid a build-up of moisture. Thus, there are air vents at the top of the enclosures, and condensate drains ("weep holes") at the bottom of the enclosures.

4.5.2 Visitor Display Panels (Sign)

Solavolt was required to design and provide a visitor display panel in each village that contained the following information for each village:

a) Project Name

b) Project Description

c) Site Plan showing Systems locations

d) Systems Descriptions (understandable by laymen)

e) Participants' Credits.

The visitor display panels were to include a registration station and log book protected from the environment where visitors may enter their names, affiliations and comments.

The basic layout for the display panels was supplied to Solavolt by MERH at the final design review. All text is in French. The visitor display panels are four (4) foot by six (6) foot signs mounted on two (2) four (4) inch diameter aluminum poles. The signs use a special surface treated aluminum sheet designed to hold paint well in a tropic environment. The text and logos were silk screened on the signs. Site maps taken from the village plans were hand-painted on the signs. The aluminum sheet is bonded to a sheet of marine plywood and the edges enclosed with an extruded aluminum channel.

The visitor registration stations that consisted of epoxy painted steel lecterns with a sheltered area for storage of visitor logs and project information were supplied. The visitor log and project informations were not the responsibility of Solavolt, and were not supplied.

SECTION 5. OPERATIONAL PROBLEMS

There were many small and a few major problems encountered either in the installation and during the first year of systems operation.

5.1 Summary of Installation and Operational Problems

Common to all Villages:

- Failure of 40 watt fluorescent lights
- Improperly installed village light runtime meters

Bolossoville Systems:

- Dispensary
  - R/F failure
  - Battery enclosure vent leaking
  - Amp-hour counter stuck
  - R/F runtime meter physical damage
  - Freezer temperature probe failure
- School
  - Irradiation sensor (open circuit, repaired)
  - Battery enclosure vent leaking
  - Low voltage disconnect failures
  - High voltage disconnect
  - Amp-hour counter stuck
  - Irradiance meter movement siezed (corrosion)
  - Ammeter meter movement seized (corrosion)
- Water
  - Incorrect pump motor installed
  - Water pump motor failure
- Village Light
  - Lamp failure
  - Ammeter meter movement failure
  - Low voltage disconnect failure
- Community Center
  - VCR failure
  - Voltage regulator failure

Donguila Systems:

- Dispensary
  - R/F(thermostat failure and Electronic Control Module (ECM) cable damage due to rats)
  - Fan timer switch failure
  - High voltage disconnect failure
  - Low voltage disconnect failure
  - Voltage regulator (2) failures

Donguila Systems (continued):

School
- VCR failure
- High voltage disconnect failure

Water
- Insufficient water being pumped (undersized PV array)
- Array VOC/ISC meter failure

Village Light
- Incorrect installation of lamp fixture
- Battery failure
- Lamp failure
- Inverter/ballast & timer changed (2) failures
- High voltage alarm (2) failures

Nyali Systems:

Dispensary
- Irradiation sensor failure
- Fan and porch light timer switches failures
- Porch light inverter & timer water damage (wrong fixture installed)
- Low voltage disconnect failure
- R/F monitor (amp-hr meters) failure

Water
- Insufficient water (valve partially closed)
- Water meter leaking and clogged with sand

Village Light: None - only place w/"None"

Onguia-Bougandji Systems:

Dispensary
- R/F failure of ECM
- Refrigerator section circulation fan damaged
- Locks missing
- Amp-hr counter stuck
- Fan timer/switch failure
- Leaking battery vent

School
- TV failed

Water
- Water pump motor failed (motor open circuit)
- Runtime meter failure
- Broken modules (vandalism)
- Broken faucet
- Blocked water line at fountain
- Instrumentation fuse blown
- Amp-hr counter stuck
- Remote water volume counter stuck

Onguia Systems (continued):

Village Light
- Instrumentation failures
- Battery connector open circuit
- Circuit breaker connections loose
- Darkness sensor failed
- Ammeter meter movement stuck (corrosion)

5.2 Common Problem Descriptions

The problems discussed in this section were encountered in all of the villages.

5.2.1 40-Watt Fluorescent Lamp Fixtures

This project originally used standard 12-volt, 40-watt fluorescent light fixtures manufactured and sold by REC Specialties as their model 153. Solavolt separately supplied G.E. "cool white" 40-watt lamps that were placed inside clear plastic "tube-gard" protective tubes so that if a tube was broken in transit or while being used, all the broken glass would be safely contained (enclosed fixtures should be avoided in Gabon, because they tend to fill up with dead insects).

The REC model 153 has an integral solid-state inverter/ballast that converts the direct current into high frequency, high voltage AC current for operating the fluorescent lamps. The circuit used is a free running, multivibrator with a transformer. The frame is steel with white paint.

These light fixtures were used in the dispensary, school, and community center systems. They provide adequate light. Each system was provided with one spare fixture and two spare lamps. During the initial planning site visit, it was determined that suitable replacement lamps were available in Libreville and Franceville. The standard European 48inch (1219mm) fluorescent lamp is rated at 36 watts, is slightly narrower, but will fit and operate in either U.S. or European light fixtures.

Problems with these lights started early in the project. One of the light fixtures failed shortly after installation in Donguila in September 1984. The Nyali dispensary was installed about four weeks later, and two of the four lights failed during the first day. Light fixtures intended for the school were used to replace the failed dispensary fixture, causing several more failures. The Nyali school system was not installed, because MERH determined that the present building was not suitable, and that the Education Ministry planned to replace the school within a year. As of fall 1986, this had not occurred.

The Onguila-Bougandji school and dispensary systems were installed about 10 weeks after the Donguila systems, and about 75 percent of the light fixtures failed within a few hours of use.

Solavolt was notified of the problem and purchased additional REC model 153 fixtures from a different production lot, applied a secondary conformal coating to the inverter/ballast, and air shipped the fixtures to Gabon. Solavolt and NASA personnel arrived for the Final Acceptance Test (FAT) visit in January 1985, and installed the replacement fixtures in Onguia-Bougandji. While the FAT team was in Onguia, the last of the Bolossoville systems were being installed by Ceca Gadis, and all of the fixtures failed upon testing. Solavolt subsequently air-shipped 24 replacment fixtures. This third shipment consisted of 12 REC fixtures and 12 from Standard Electric Fixture Company. The Standard Electric Fixture Company fixtures use Iota 1D12-40 inverter/ballasts. These 24 fixtures were installed in Bolossoville in February, 1985.

During the first year of operation, the REC fixtures continued to fail, but at a reduced rate. During the Final Inspection Test (FIT) visit in February 1986, several more failed fixtures were replaced, and many failed 40-watt lamps were found and replaced. A review of the failed fixtures indicated that all production lots of the REC fixtures had significant failure rates, and that the secondary conformal coating of the inverter/ballast had little, if any, affect on the mortality rate. There was a very strong correlation between the storage time in the tropic environment and the initial failure rate of the REC fixtures. Significantly, none of the Standard Electric Fixture Company fixtures with Iota ballasts are known to have failed to date.

Many of the failed inverter/ballasts were returned to the manufacturer for analysis, but Solavolt has been unable to obtain a satisfactory reason for fixture failure. The manufacturer stated only that the power transistors had burned out (shorted or open circuited), and replaced all submitted failed inverter/ballasts with new units of the same design. Because of REC's reluctance to give a reason for their failures and the good field performance of the Standard Electric Fixture Company product, all replacement fixtures sent to Gabon as a result of the FIT visit are from Standard Electric Fixture Company.

The high failure or burn-out rate of the fluorescent lamps was unexpected. The lamps are rated for an average life of 10,000 hours at 4 hours per start. Long lamp life is important in this application, because the village schools and dispensaries do not have ready access to replacement lamps, and do not have funds to pay for the lamps.

Solavolt investigated the short lamp life problem, and determined that the short lamp life experienced in this project is caused by another characteristic of the REC inverter/ballast. All fluorescent lamp manufacturers specify that the Current Crest Factor (CCF) of the waveform of the power applied to the lamp must not exceed 1.8. The CCF is defined as the ratio of the peak current to the root mean square (rms) average current. Solavolt has measured the CCF of representative Iota and REC inverter/ballast, and determined that the Iota inverter/ballasts meet this requirement, while the REC inverter/ballasts exceed the allowable limit. The use of the Standard Electric Fixture to fixtures as replacements for the failed R5C fixtures should greatly improve the life of the fluorescent lamps.

5.2.2 Village Lights

The village lights use a REC model 118 18-watt Low Pressure Sodium (LPS) light fixture with darkness sensor and timer. The dispensaries use the same basic light fixture without darkness sensor and timer as a porch light. Several problems were encountered with the use of these fixtures.

In Nyali, a village light model lamp fixture was installed by mistake as the dispensary porch fixture, and the darkness sensor was removed so that it would operate properly with the manual switch. Removal of the darkness sensor left the socket for the sensor exposed, and allowed rain water to enter and fill the entire fixture with water, causing complete failure of the fixture and the timer switch controlling it. In Donguila, the timer circuit board for the village light was replaced twice in the 16 month period. The problem may have been caused by a shorted battery cell. At least one of the removed timers operated to specification when retested by the manufacturer. In Onguia, the darkness sensor required replacement during FIT.

All the village lights required replacement of the LPS lamp at least once during the year. This is believed to be related to the inverter/ballast CCF characteristic as described for the fluorescent lights. Additional spare lamps were furnished for each system.

5.2.3 Voltage Regulators

The voltage regulators used in the 12-volt systems had an unacceptable failure rate. During the 16 months from the first installations until the FIT visit in February 1986, six voltage regulators out of the total of 32 installed had failed. The voltage regulators used are Specialty Concepts' SCI Charger Model 2 without temperature compensation capability. Solavolt specified several modifications to these units including conformal coating of the printed circuit board with a MIL-specification coating, an array input fuse, and French language markings.

All failed units were returned to the manufacturer, Specialty Concepts, for analysis. Solavolt and Specialty Concepts determined that one unit removed from service by Ceca Gadis as defective was fully functional. Five (5) of the units had various types of component electrical damage that was attributed to electrical transients. Specialty Concepts stated in a letter to Solavolt concerning the failure analysis that: "The parts which we have replaced have had no history of failure on previous units". One regulator was found to be full of insect mud nests that caused damage to components. A review of the system designs does not indicate any design feature that can be changed to reduce transients. Since no specific cause of this problem was determined, it was decided to increase the number of spare voltage regulators so that system operation could be maintained.

5.2.4 High and Low Voltage Disconnects

Another Specialty Concepts product used in the control system also had a high failure rate. The Specialty Concepts "Battery Saver" was used in two versions, one for load disconnect in the event of low voltage, and the other as an array disconnect, and in the event of voltage regulator failure. Nine out of 28 of these units installed for the project failed during the 16-month operational period. Several were repaired in Gabon by Solavolt by replacement of a transistor (MPS-A13) that activates the relays. The rest of the failed units were returned to Specialty Concepts for analysis and repair/replacement. Specialty Concepts determined that the MSP-A13 transistors had been damaged by transients. As with the voltage regulators, NASA and Solavolt decided to increase the number of spare battery savers as the only practical solution to the problem.

5.2.5 Ampere-Hour Meters

Many minor problems were associated with the Curtis Instruments ampere-hour meters used in all systems. These instruments use Triplett Model 320-R 0-1 milliampere meter movements to indicate system voltage and currents. The humid tropical climate caused corrosion in these meters that resulted in sticking and non-functional display of the measured quantity. A total of 8 out of 67 meter movements required replacement. Several of the electro-mechanical counters used to accumulate the ampere-hour readings stuck at various times, but were restored to operation by either resetting or application of a higher voltage pulse. One of the instruments (Onguia village light) did not function when installed. This was traced to transistors Solavolt improperly installed in the unit, and was responsible for loss of data from the system for the entire 16-month period, because Ceca Gadis did not replace the unit after in-Gabon repair by Solavolt during FAT.

Significantly, there were no operational failures of the integrating electronics in the Curtis Instruments ampere-hours instruments even though the electronics involved are far more complex than those in the voltage regulators and high/low voltage disconnects.

5.2.6 Battery Enclosures

An example of how a simple problem could lead to serious problems if not corrected is the problem encountered with the battery enclosures used for the large industrial batteries in the school, community center, and dispensary systems. Water leaks developed around the air vent which allowed water to drip on the batteries. This additional water entered the battery cells directly below the vent and diluted the battery acid. If the situation was allowed to continue, it would lead to premature failure of the batteries. The leakage could be temporarily stopped by resealing the joint between the vent and the top of the enclosure, but the experience gained between the FAT and FIT visits was that leaks redeveloped. The resolution was to cut a piece of wood to the height needed to fit inside the enclosure and lift the vent slightly so that rain water would flow away from the joint. This was done for all the systems.

5.3 Dispensary Systems

5.3.1 Refrigerators

Three of the four refrigerators failed during the 16 month operational period. Failure of the Donguila dispensary refrigerator was caused by rodents chewing through the instrument cable at the rear of the refrigerator, thus causing a short circuit that further caused a transistor to burn out on the thermostat card of the refrigerator. The transistor was replaced by Solavolt during the FIT visit. The other two refrigerators failed due to failures within the Danfoss Electronics Control Module (ECM) that powers the compressor.

In Bolossoville, the part of the ECM that controls the condensor fan failed to operate the fan, resulting in continuous operation of the compressor. The cause of the continuous operation of the compressor was misdiagnosed by Ceca Gadis, and the refrigerator was removed to Libreville for recharging with freon. Before any attempt was made to repair the refrigerator, Solavolt and NASA personnel arrived for the FIT visit, properly diagnosed the problem and replaced the ECM. At the same time, it was discovered that the reverse polarity protection circuit breaker had corroded and was causing on open circuit. That corrosion problem was corrected.

During the FIT visit, the refrigerator in Onguia was found to have failed (there was no one assigned to the dispensary). The problem was traced to a failed ECM, which was replaced.

All failed ECM units were returned to the refrigerator manufacturer (Marvel) and replaced, but Solavolt has not been able to obtain any failure analysis.

5.3.2 Timer Switches

Timer switches were used for the dispensary outdoor porch lights and the ventilation fans, so that these load devices could not be left on all the time by mistake. The timer switches are manufactured by SunAmp Systems, and are designed to fit a standard U.S. electrical outlet box. The electrical outlet boxes used in the project were surface mounted Wire Mould boxes, and the timer switches were difficult to correctly insert into these boxes. As a result of this, two of the timer switches were broken during the installation task. Another timer switch (Nyali dispensary) failed when the porch light short-circuited due to water inside the fixture. During the 16 months of operation, three additional timer switches failed due to mechanical damage by the users, corrosion, and electrical transients.

During the FAT visit, it was obvious that a timer switch was not needed, and that the users could handle the responsibility of assuring that unneeded devices should be turned off. As a result, all the timer switches were replaced with standard mechanical switches during the FIT visit.

5.4 School and Community Center Systems

5.4.1 Irradiation Sensors

Each village was supplied with an instrument to measure the intensity of the sunshine and accumulate the irradiation (insolation). The insolometer for each village was included with the school system PV array and instrumentation. The insolometer sensor is a Li-Cor LI200-SB silicon pyranometer. The instrumentation use a ten-turn miniature potentiometer to adjust the output voltage to an exact 10 millivolts under an irradiance of 100 milliwatts per square centimeter. In Bolossoville and Nyali, this potentiometer developed an open circuit between the resistance element and the wiper. During FIT in Nyali, it was discovered that a slight adjustment of the potentiometer would restore operation. This was not known during the earlier Bolossoville FIT visit, and was not corrected. A spare sensor has been sent to Gabon, and Ceca Gadis has been instructed on how to repair and replace the sensor.

5.4.2 TV and VCR

Both the TVs and VCRs were subject to several failures that are characteristic of these devices in this climate. They were routinely repaired by Ceca Gadis.

5.5 Water Systems

5.5.1 Water Pumps

The water pumps used in this project have had some problems. The water pump installed in Onguia-Bougandji and powered by a 1760 watt array failed after 10 months of operation. The pump motor was replaced during the FIT visit in 1986, and the motor was returned to the manufacturer (Jacuzzi) for analysis. It was determined that the commutator and brushes were completely burnt up - cause unknown.

The pump at Bolossoville initally failed to pump the required amount of water and was observed to stop pumping when the current from the 3.2 kW PV array exceeded 20 amperes. Analysis of the situation indicated that the wrong pump set, an SJ1 instead of an SJ2, had been installed at Bolossoville. The cause of the failure to pump at array currents over 20 amperes was the proper operation (slippage) of a magnetic coupling between the motor and pump. The pump and motor was removed and returned to the manufacturer for inspection before being returned to the spare parts supply in Libreville. The manufacturer determined that the motor had been damaged, and the motor was rebuilt.

During this first replacement operation in Bolossoville, the personnel apparently did not fully tighten the fitting holding the HDPE pipe at the top of the well. This fitting later separated allowing all water pumped to fall back into the well and resulted in the pump and pipe hanging from the well head fitting by the safety rope and power cable.

During FIT, an attempt was made to raise the pump and pipe by the safety rope, and to reconnect the pipe to the well head fitting. However, the pump was securely lodged in the well casing and the safety rope broke, allowing the pump and pipe to drop to the bottom of the well. A special tool was sent to Gabon to extract the pump by catching the pipe where it had come to rest about five meters below the well head. The pump is apparently caught securely on the bottom of the well casing, however, and could not be dislodged. The efforts to remove the pump were semi-successful in that the effort broke the pipe connection at the pump and the removal of all of the pipe and wiring was removed from the well. A replacement pump and motor was installed in the well.

The condition of the first motor removed from the well prompted the development of a protective automatic array disconnect switch that disconnects about 40 percent of the array when the current approaches the pump manufacturer's maximum rating. This additional circuit was installed when the replacement pump was installed.

The water system in Donguila did not produce an adequate flow of water as initially designed. A definite cause was not found, but data taken indicated that the level of water in the well was lowered more than expected by the operation of the pump resulting in a reduced pumping rate. To correct this problem, sixteen modules were added to the array just prior to the FIT visit. Present indications are that the supply of water is now adequate.

The pump in Nyali initially produced substantially less water than desired. This was determined to be caused by an almost completely closed valve between the well and the water tank. Prior to this discovery, plans were made to add three modules to the fifteen installed so that more water could be pumped. Since the modules and wiring were already in the village when the cause of the problem was discovered, they were installed. These additional modules necessitated the replacement of the system ammeter with a different ammeter capable of measuring the higher current.

5.5.2 Pump Runtime Meters

The pump runtime meter in Onguia failed during installation, and was not replaced until the FIT visit 16 months later. Cause of failure was not determined as the failed unit was lost during the FIT visit.

5.5.3 Distribution Plumbing

Some problems were encountered with the water distribution system plumbing. Because of decisions to add additional fountains in Donguila and Onguia-Bougandji, self-closing faucets were purchased in Gabon for these fountains. Those faucets were of a different design than the U.S. faucets, and developed a serious leak problem. They were replaced during the FIT visit.

The U.S. faucets developed a problem that the local plumbers did not know how to correct. In those faucets, the spring that returns the faucet to the off position also holds the knob tight against a pin inside the knob. After extensive use, the spring weakens slightly, and the knob develops a wobble. The adjustment for this condition is hidden under a decorative emblem on the knob and access requires a pair of pliers. During the FIT visit, all the knobs were adjusted, by SVI and the local people shown how to make the adjustments.

At FIT, one of the water fountains in Onguia was discovered to be plugged. This problem was brought to the attention of Societe D'Energie et D'Eau Du Gabon, and they were to correct the problem. Road work in Bolossoville resulted in the cutting of the pipe where it crossed the road. S.E.E.G. personnel from Oyem repaired the break.

5.6 Village Light Systems

5.6.1 Batteries

The only problems with batteries were with the Delco 2000 batteries used with the village light systems. In Donguila, one of the Delco batteries developed a short circuit in a battery cell. The low voltage produced in the parallel battery caused that battery to lose most of its capacity. The problem was discovered during the FIT visit, and both batteries in the system were replaced with available spares.

In Onguia, one of the batteries in the village light failed. This was discovered during the FIT visit, and was caused by an open circuit in the cable connecting the two parallelled batteries. The deeper daily cycling resulting from only one battery being connected caused failure of that battery. The system was left with only the unused second battery operating until replacement batteries and cable could be furnished.

Since the village lights were originally designed, an improved series of batteries has become available. The GNB 12-5000 battery is a sealed, absorbed electrolyte battery that has excellent deep-cycling life. Following FIT, a decision was made to replace all of the village light systems with GNB 12-5000 batteries.

5.7 Miscellaneous Problems

The FIT visit, and to a lesser extent the FAT visit, resulted in the discovery of many minor systems problems that were corrected.

In Nyali, the water meter became clogged with sand from the well. Solavolt disassembled the water meter and cleaned it out during the FIT.

In Onguia, it was discovered that the screw connections on the rear of the circuit breakers in the village light instrumentation had never been fully tightened and were causing intermittant open circuits.

This was corrected. Also in Onguia, three of the modules for the water system were broken by children throwing rocks down a hill and onto the array. The modules were replaced. When told of the problem, the village chief strongly reprimanded the children.

Several of the keyed-alike padlocks disappeared during installation and the operational period. They were replaced with spares, but future projects should consider the use of padlocks with short chains to fasten them in place.

Section 6. SYSTEMS PERFORMANCE REVIEW

The data on system performance was recorded in the villages by selected individuals who received about four hours of training. The data was to be collected by S.E.E.G., forwarded to MERH in Libreville, and mailed to Solavolt for analysis. The data was recorded on multi-part carbonless forms that provided copies for each agency and a heavier paper copy designated to remain in a logbook with the system. Only half of the data reported herein was collected in the intended manner; the rest was retrieved from the system sites during the FIT visit in 1986.

The data was processed at Arizona State University under subcontract to Solavolt. The tabular data was plotted to identify data problems. Most of the inconsistencies in the data were resolved, but some unexplainable problems remain. Typical problems were misreading of instruments or handwriting, the rolling over (from 9999.00 to 0000.00) of mechanical counters for integrals of current and irradiance, and missing or incorrect decimal points.

Missing data for some systems (due to instrument failures) prevented some desired analyses. The use of integrating counters provided useful data that spaned periods of missing data.

This section is organized with a text description of the system performance, a tabular summary of the design parameters, and graphical plots of data. The graphical plots contain measured data and parameters derived from the measured data such as daily cubic meters of water pumped vs. daily ampere-hours.

The following terms used in this report are specifically defined as follows:

POTENTIAL ARRAY OUTPUT - INSOLATION multiplied by ARRAY RATED CURRENT (ARRAY RATED CURRENT = NUMBER OF PARALLEL MODULES multiplied by MODULE RATED CURRENT of 2.45 amps)

ACTUAL ARRAY OUTPUT - As measured by the current integrators

$$\text{PERCENT ARRAY CAPACITY UTILIZATION} = \frac{(100) \times (\text{ACTUAL ARRAY OUTPUT})}{\text{POTENTIAL ARRAY OUTPUT}}$$

The text description for each system summarizes the performance, problems, and the effect the problems had on system performance.

The tabular data attempts to compare the design objects to the field performance. Two types of field data were available: single day data taken by NASA and Solavolt during the FAT and FIT visits, and the routine data recorded by the villagers. Some of the design parameters cannot be compared to the instantaneous measurements taken during the FAT and FIT visits.

The graphical plots illustrate most of the reported data and are annotated with related average data and notes regarding discrepancies.

6.1 Water Systems

6.1.1 Bolossoville Water System

The Bolossoville water system experienced several problems during the first year of operation. The pump motor originally installed was a Jacuzzi SJ1, not SJ2 as required by the design. This was the result of an equipment distribution error by Solavolt. The difference between the motors is the torque rating of the magnetic coupling. Shortly after installation, it was discovered that the pump current would drop to a very low value after exceeding twenty amperes. It was determined that this was due to high torque decoupling the magnetic coupling between the pump and the pump motor. To avoid this problem, three of the seven array branch circuits were disconnected until the pump motor was replaced with a model SJ2 in April 1985. This action reduced maximum array current to the pump and allowed the pump to operate properly during the mid-day, albeit at some loss of pump output at low sun times. The SJ1 motor was returned to the U.S.A. and found to have a burnt commutator, but was reported to have been operating properly when removed.

In December 1985, the pump stopped producing water. During the FIT visit, it was determined that the well pipe had become disconnected from the well head resulting in water being pumped up the well pipe and then spilling back into the well (see paragraph 5.5.1).

Data collection throughout this period provided on accurate account of system performance as can be seen on the following graphs and tables. The graphs of array ampere-hours per day, cubic meters of water pumped per day, and pump run-time per day show two different rates. Even though these rates should be more consistent, the activities of the villagers (i.e., water requirements) could change those factors. The major dry season is usually July through September, and is the likely reason for the higher water usage during this period. The graph water volume pumped versus array ampere-hours has a constant slope of 0.13 M^3/AH. This states that there is a direct correlation between these parameters. Other parameters that should have a direct correlation are volume of water pumped and pump runtime versus insolation. Those parameters have variable rates showing system performance changes.

A comparison of design parameters and performance data (Table 6-1) shows, based on yearly data, that the system did not produce as much water as expected by the design. Instantaneous readings (FAT) for volume of water pumped versus insolation show greater performance than both the yearly data and design objectives. Volume of water pumped per hour and per ampere-hour show a good correlation for FAT and yearly data. This instills confidence in the system operation.

Table 6-1. Bolossoville Water System Performance Data

	Design Parameters	Final Acceptance Test Data (FAT) 2/4/85	Operational Data Low-High	Final Inspection Test Data (FIT)
Insolation ($kW\text{-}HR/M^2$)	4.16	4.1	3.5-4.4	System not operating: see section 5.5.1
Potential Array Output (amp-hours/day)	191	189	161-202	
Actual Array Output (amp-hours/day)	NA	ID	29.7-52.1	
Array Capacity Utilization (percent)	NA	ID	19-26	
M^3/day	9.7	ID	3.78-6.64	
Run-time/day (hours/day)	NA	ID	3.0-4.8	
$M^3/kW\text{-}HR/M^2$(1)	2.33	6.16	0.74-1.52	
M^3/Hour	NA	2.28	1.3-2.4	
M^3/Ampere-HR	NA	0.13	0.13	

FI=Failed Instrument
ID=Insuffficent Data
NA=Not Applicable

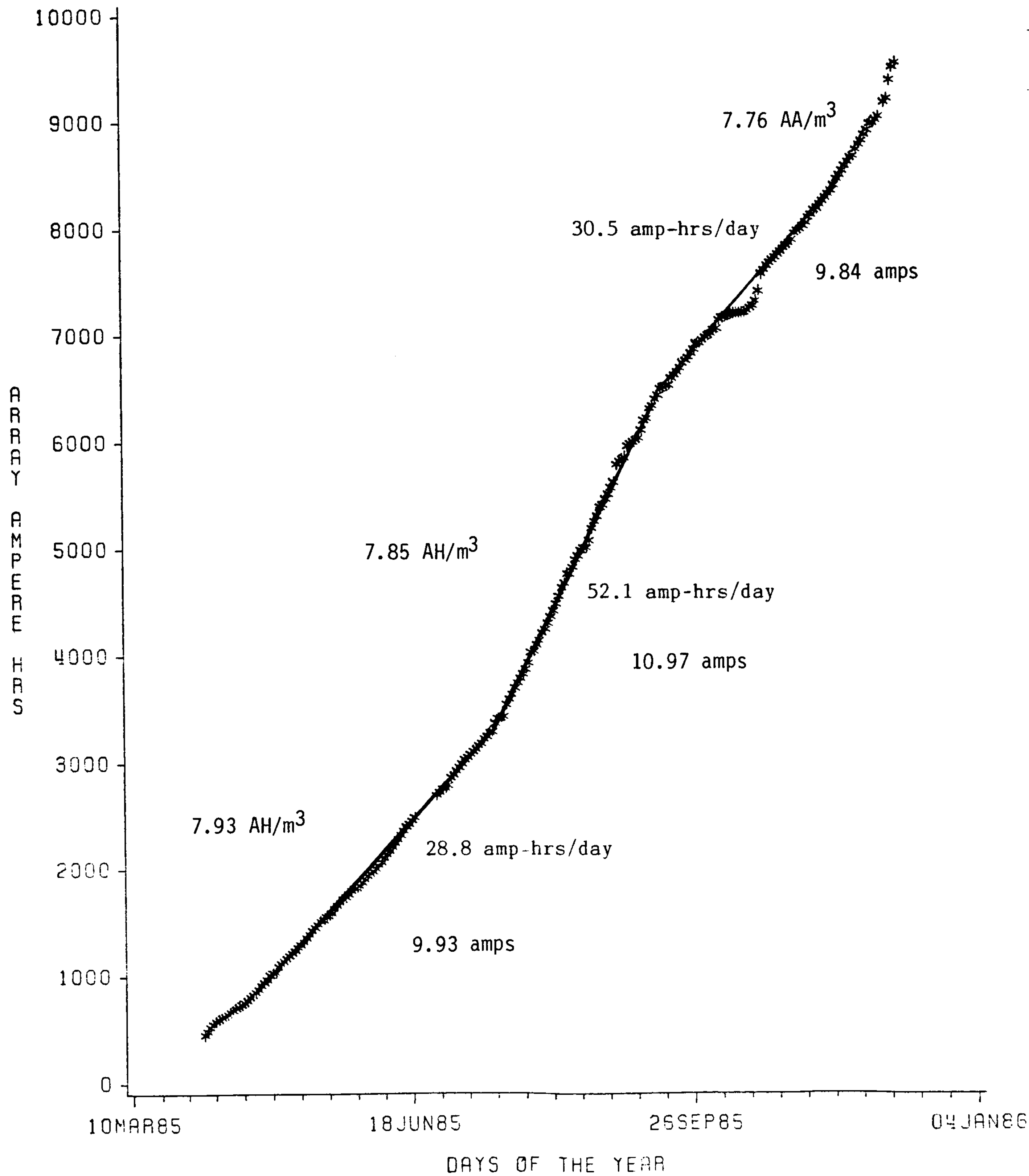
Note: Pump performance data presented in FAT are instantaneous values, not daily readings.

(1) of array area

FIGURE 6-1

BOLOSSOVILLE DATA

WATER PUMPING DATA
ARRAY AMPERE HRS. VS. DATE

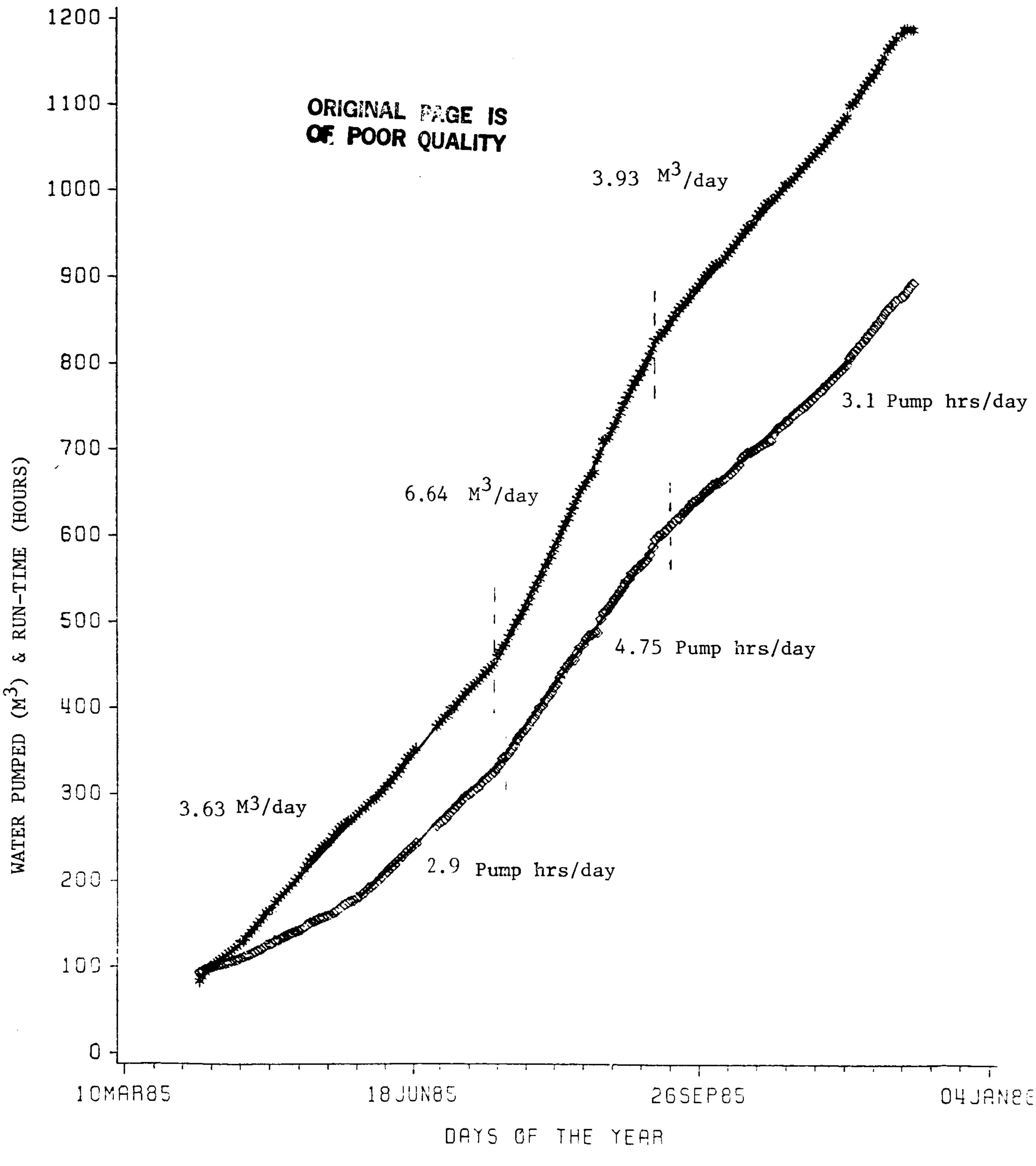


AS OF FEBRUARY 4, 1986

FIGURE 6-2

BOLOSSOVILLE DATA

WATER PUMPING DATA
M^3 , HRS VS. DATE

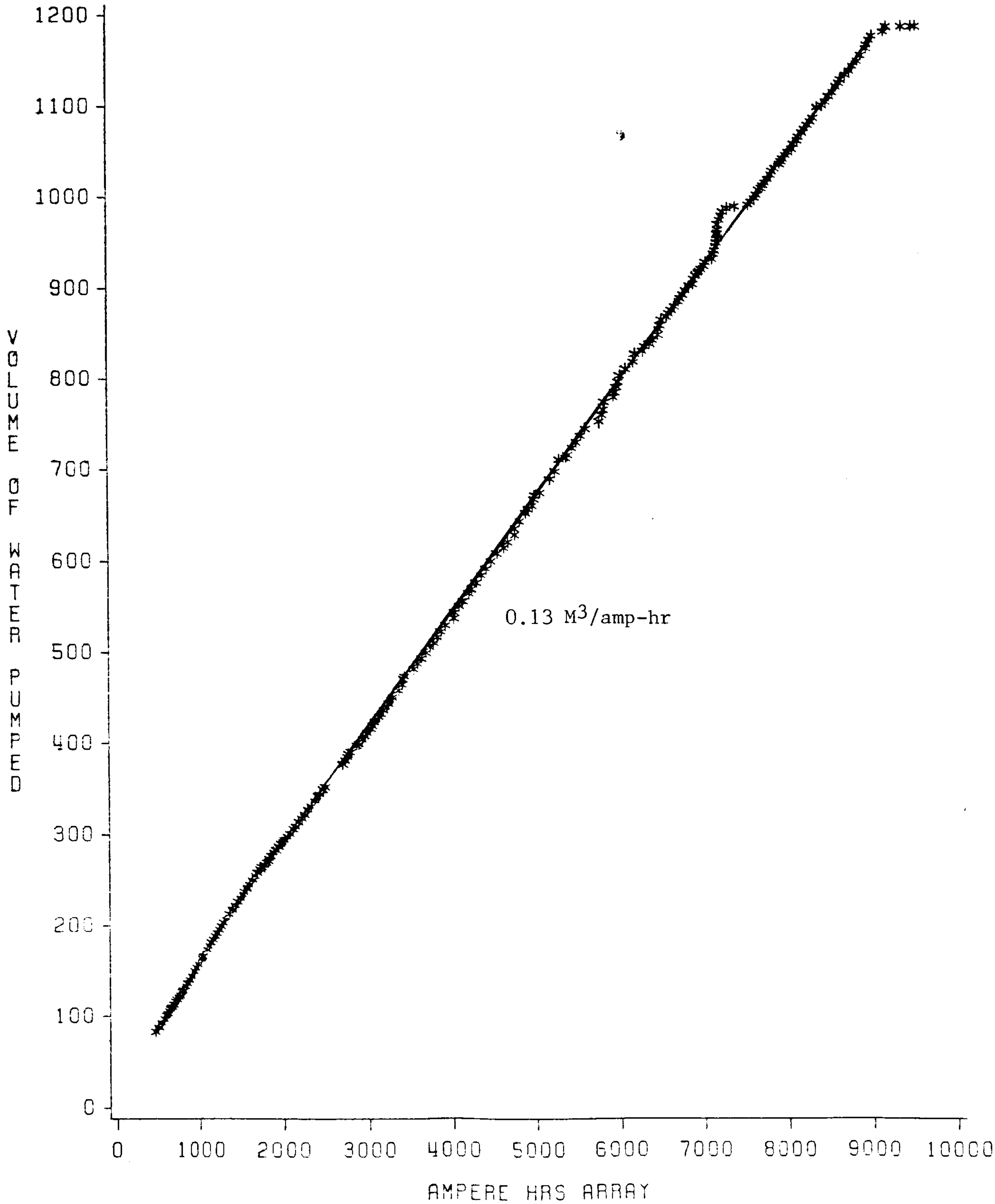


STAR: VOLUME OF WATER PUMPED
DIAMOND: HOURS OF PUMP OPERATION
AS OF APRIL 4, 1986

FIGURE 6-3

BOLOSSOVILLE DATA

WATER PUMPING DATA
WATER VS. ARRAY AMPERE HOURS



AS OF APRIL 4,1986

6.1.2 Donguila Water System

The Donguila water system operated without failure, but generated complaints of insufficient yield. Data collection throughout the year was adequate for performance analysis despite a one-month and a three-month gap in data collection. Changing volumes of water pumped per pump run-time hour show different operating characteristics. These could be attributed to changes in either well or pump characteristics.

In October 1985, the pump was temporarily removed from the well to check for mechanical causes for the unsatisfactory yield, and the well's characteristics were remeasured by MERH. No problems were found to account for the low level of performance. Complaints of insufficient yield decreased after the testing, but the data does not indicate any major change in system performance.

Refering to Table 6-2: FAT, operational, and FIT data show little correlation except that FAT array output data correlates with low operational array output data. Just prior to the FIT visit, the array was increased from 0.96 kW to 1.44 kW in an attempt to increase water yield. FIT data do not correlate this, because the data was recorded after the array size was increased. FAT data meets, and FIT data exceeds, the design parameter of volume of water pumped per day. Cumulative operational data shows performance was less than design parameters prior to increasing the array size.

Figures 6-4 and 6-5 show system performance over time (30 November 1984 through 14 April 1986) as a function of array AH produced and pumped water volume, respectively. Figures 6-6 through 6-8 diagram water volume as a function of array AH, pump run-time, and total energy in kW-hr, respectively.

Table 6-2. Donguila Water System Performance Data

	Design Parameters	Final Acceptance Data (FAT) 1/18/85	Operational Data Low-High	Final Inspection Data (FIT) 2/17/86
Insolation ($kW-HR/M^2$)	4.16	6.8	4.4-5.1	5.8
Potential Array Output (amp-hours/day)	77	125	81-94	107
Actual Array Output (amp-hours/day)	NA	66.7	65-75.6	91.5
Array Capacity Utilization (percent)	NA	53	80	86
M^3/day	4.5	4.41	2.3-3.5	6.2
Run-time/day (hours/day)	NA	FI	2.9-4.2	3.32
$M^3/kW-HR/M^2$	1.1	0.65	0.56-0.65	1.07
M^3/Hour	NA	0.74	0.82-1.24	1.87
M^3/Ampere-HR	NA	0.07	0.04-0.05	0.07

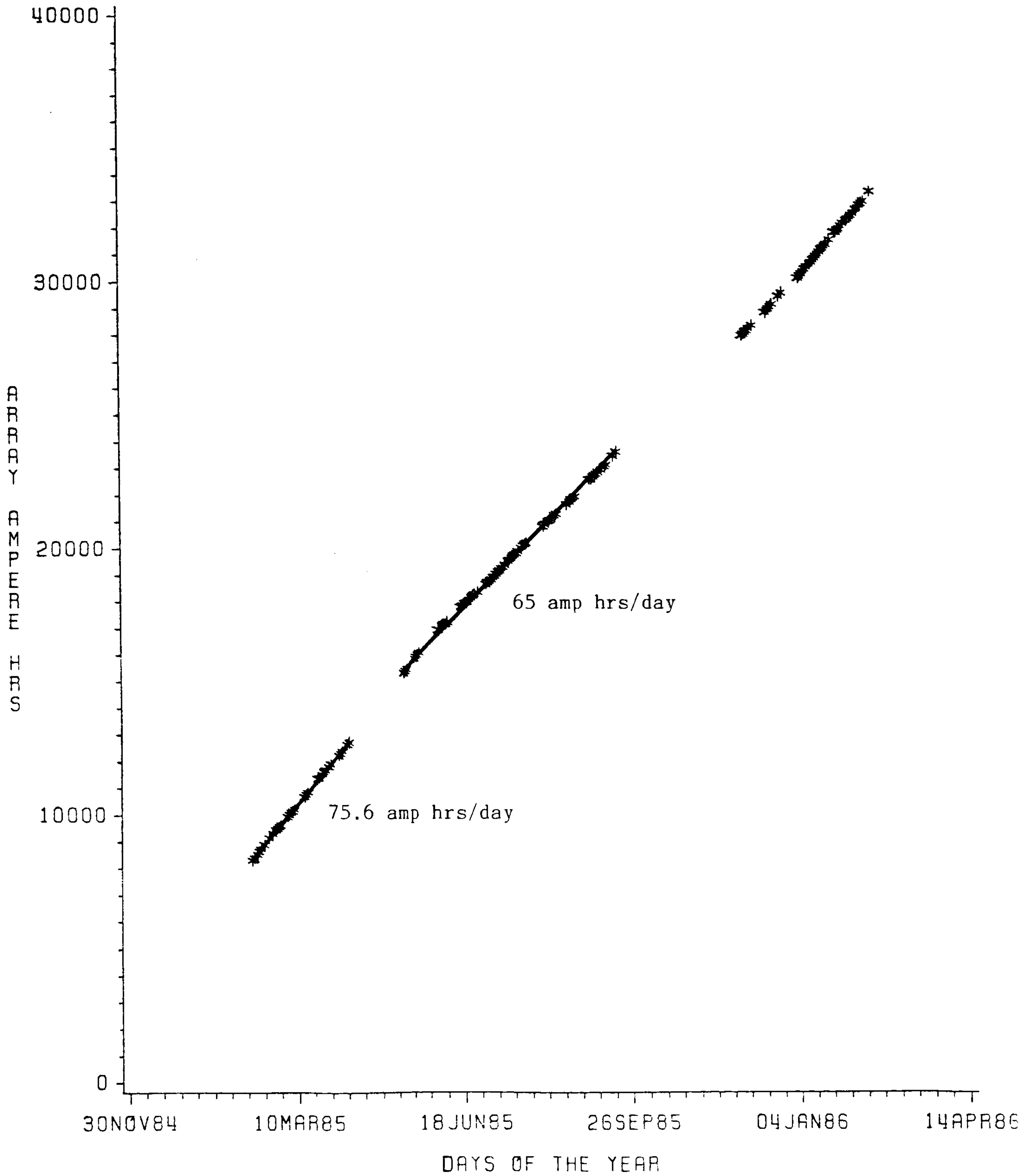
FI=Failed Instrument
ID=Insufficent Data
NA=Not Applicable

Note: FAT & FIT pump performance data are instantaneous values or data taken over the course of one day and not daily readings.

FIGURE 6-4

DONGUILA DATA

WATER PUMPING DATA
ARRAY AMPERE HRS. VS. DATE

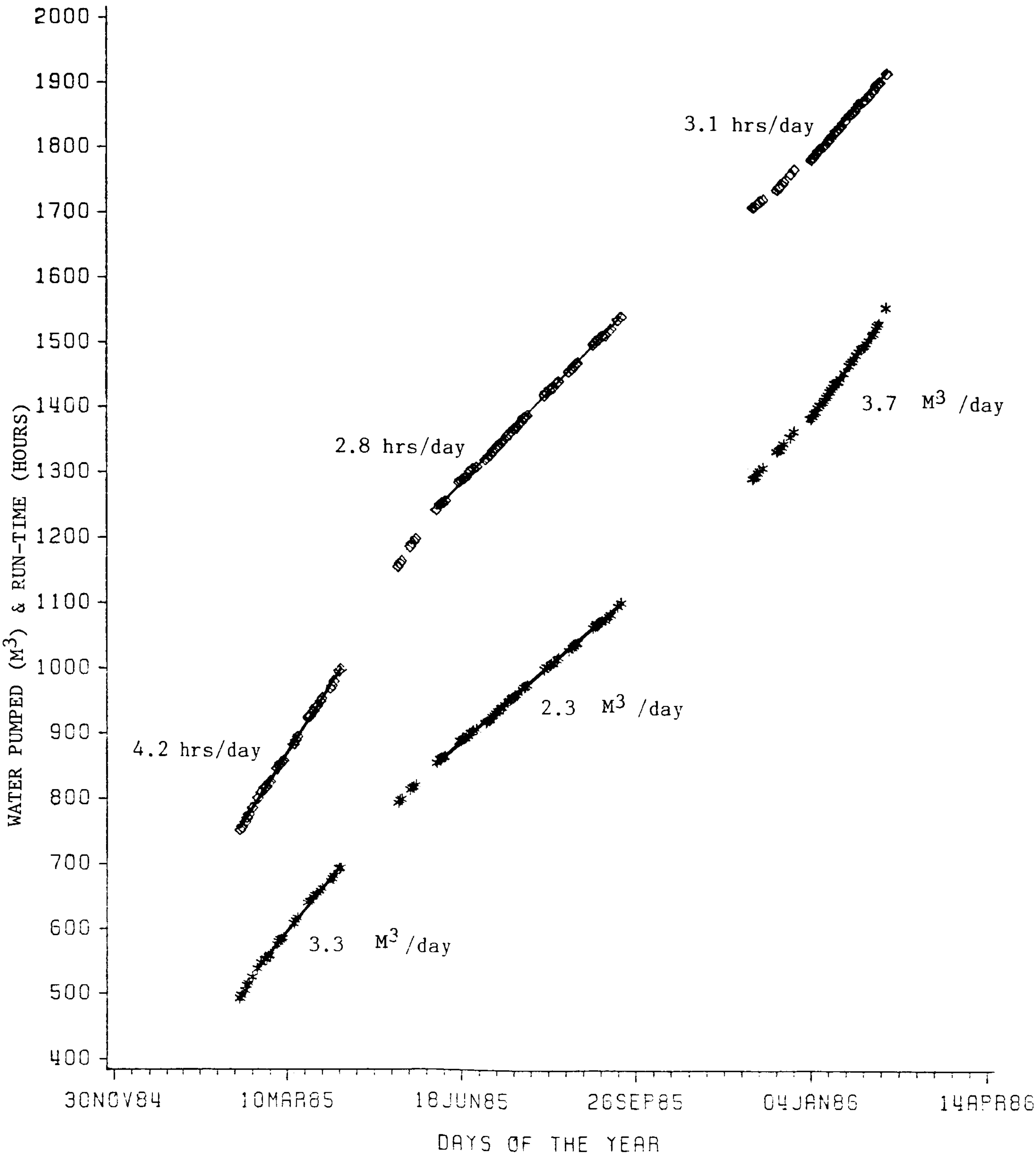


AS OF APRIL 4, 1986

FIGURE 6-5

DONGUILA DATA

WATER PUMPING DATA
M^3, HRS VS. DATE



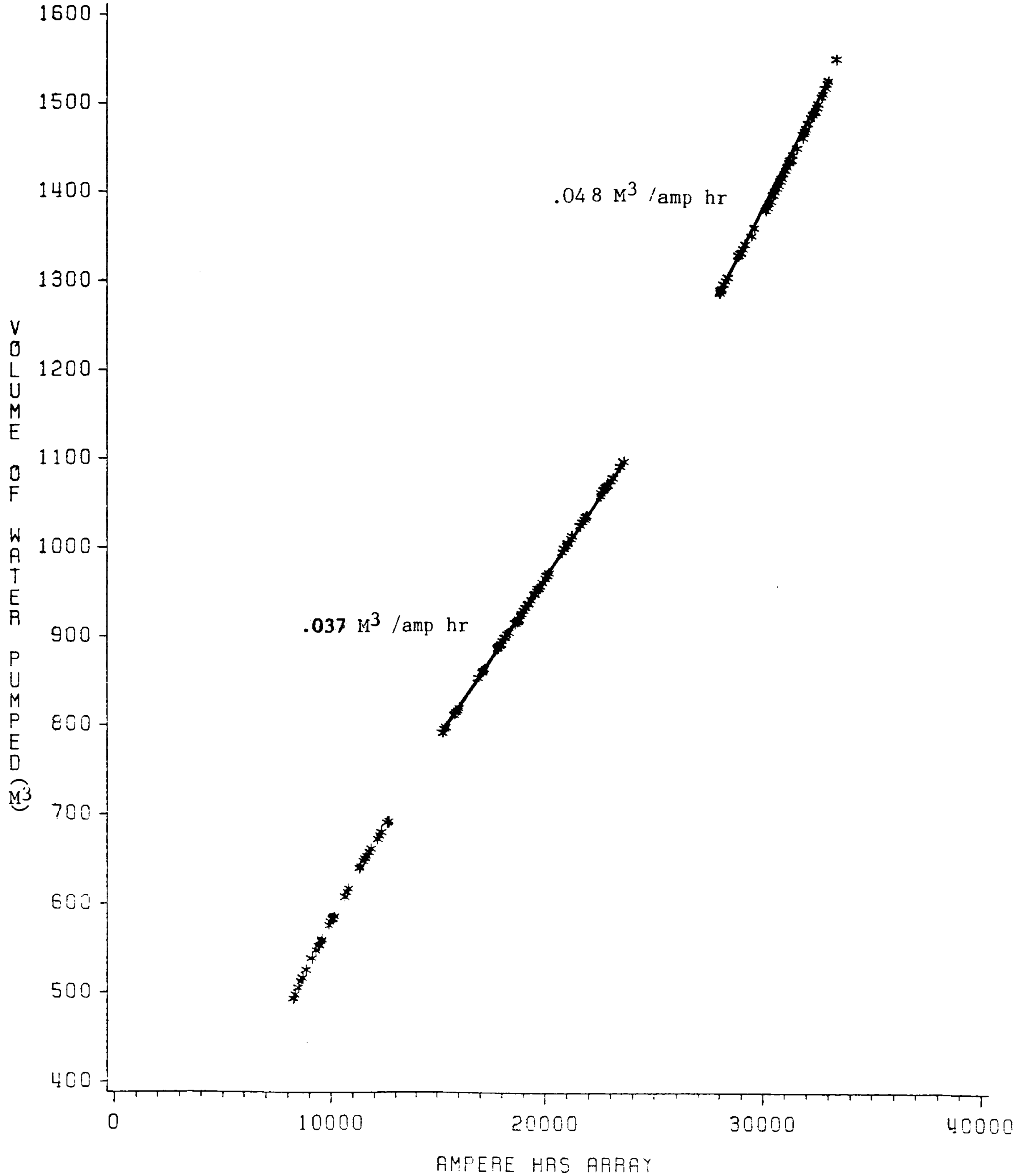
STAR: VOLUME OF WATER PUMPED
DIAMOND: HOURS OF PUMP OPERATION
AS OF APRIL 4, 1986

FIGURE 6-6

DONGUILA DATA

WATER PUMPING DATA

M^3 WATER VS. ARRAY AMPERE HOURS



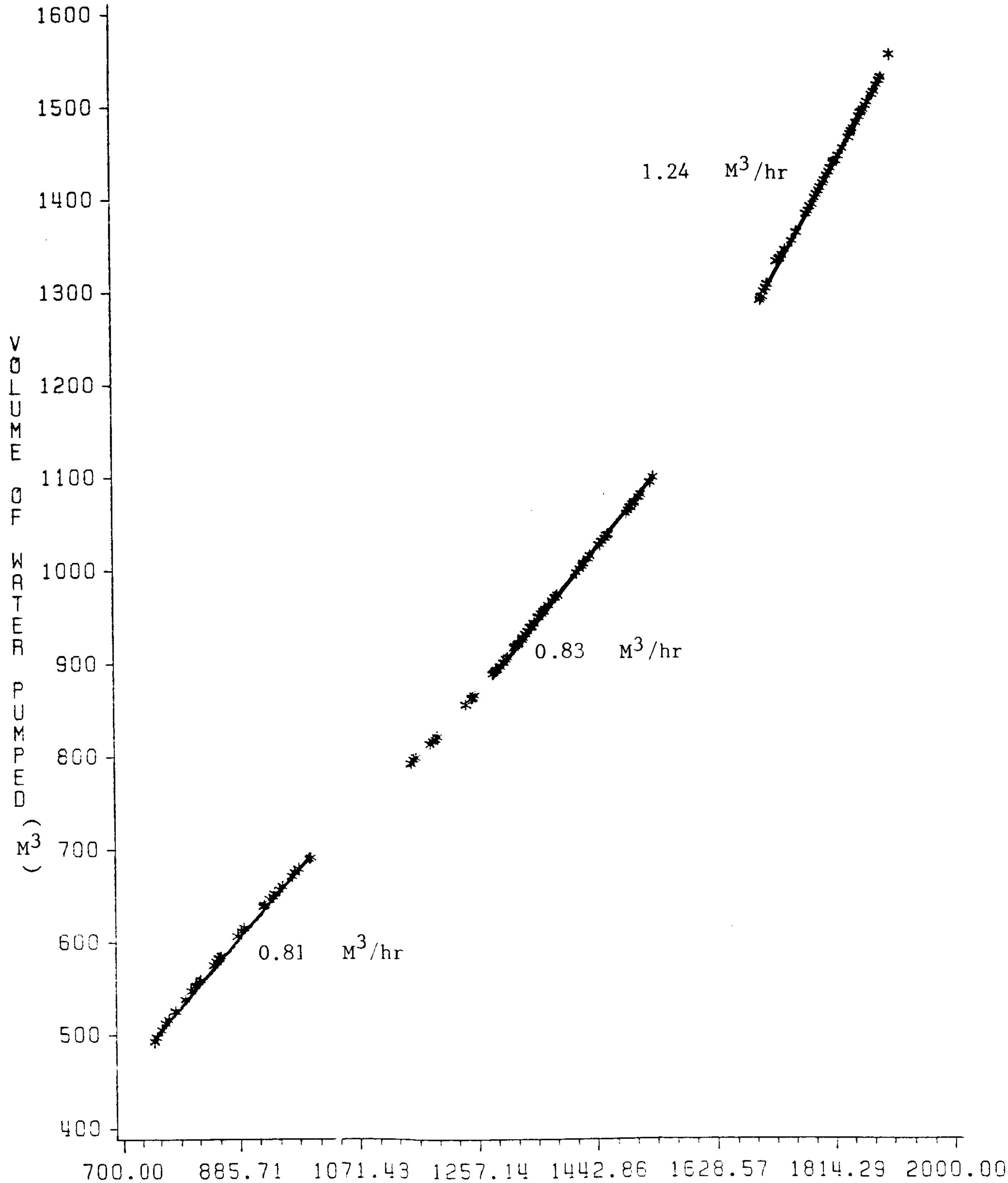
AS OF APRIL 4,1986

FIGURE 6-7

DONGUILA DATA

WATER PUMPING DATA

M^3 WATER VS. PUMP OP TIME (HOURS)

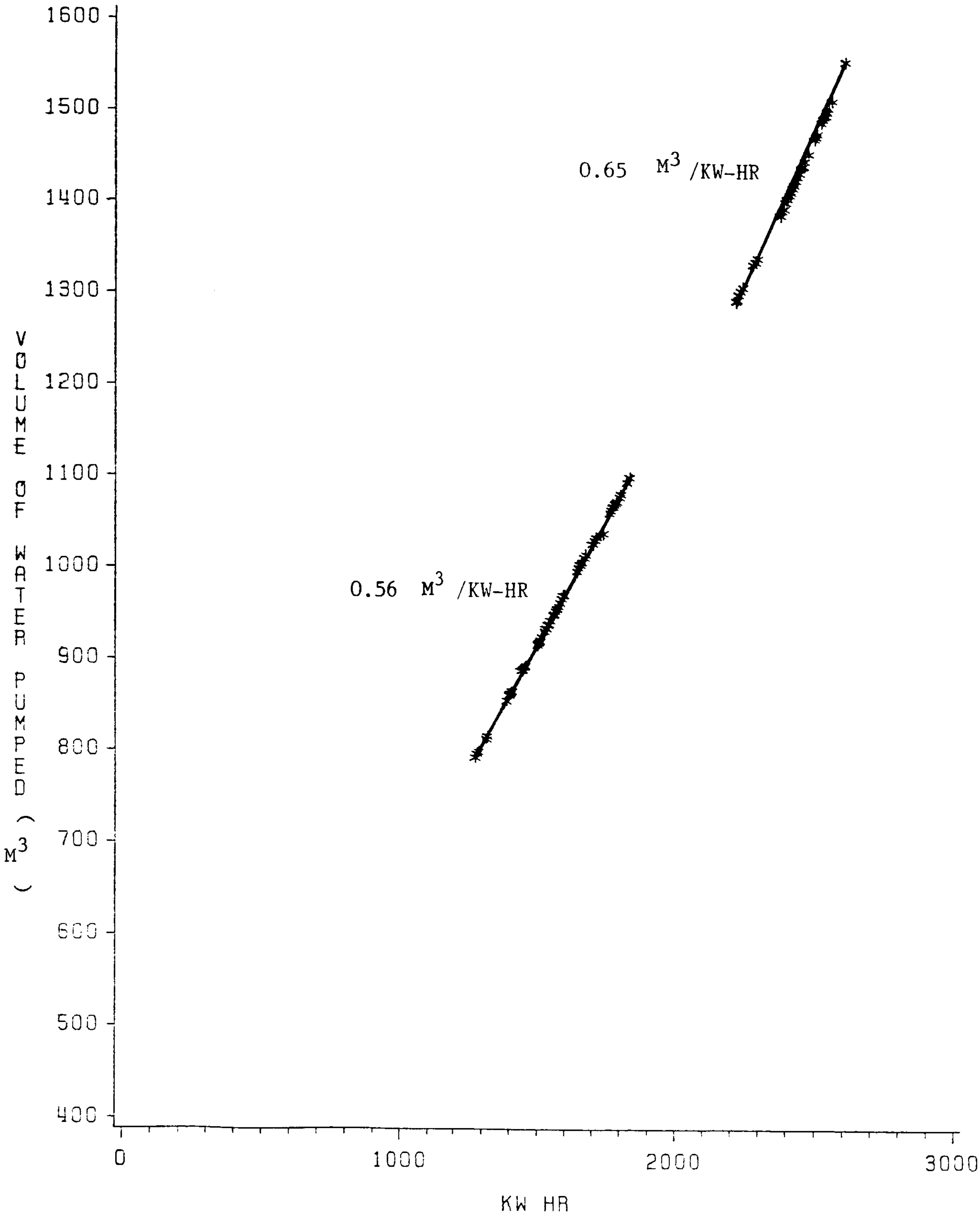


AS OF APRIL 4,1986

FIGURE 6-8

DONGUILA DATA

WATER PUMPING DATA
M^3 WATER VS. INSOLATION KW-HR



AS OF APRIL 4,1986

6.1.3 Nyali Water System

The Nyali water system operated without a system failure from January 1985 through February 1986, but had either an instrumentation failure or a data collection error during April and May of 1985. For undetermined reasons, the water pump ampere-hour data rose rapidly during the period 25 March to 27 May 1985. Insolation data was not taken during this period, but the cumulative readings showed the same effect (see paragraph 6.2.3).

Data collection was incomplete from August 1985 to January 1986, thereby providing only a partial description of the system's performance. During the year, the flow rates of cubic meters of water pumped per array output and irradiation (kW-hr/m^2) were constant at 0.11 and 0.55, respectively. Cubic meters of water pumped per run-time hour ranged from 0.29 to 0.59 with the yearly average being 0.44 (yearly average = FIT-FAT/number of days). Some of the indicated variance is due to the effect of sand from the well accumulating in the water meter. During the FIT visit, the water meter was found to be non-functional due to a sand buildup. The water meter was disassembled and cleaned.

FAT, operational, and FIT data have the same flow rates for cubic meters of water pumped per actual array ampere-hour, but have different flow rates for cubic meters of water pumped per kW-hr and cubic meters per pump run-time hour. These various rates show different pump performance levels that could be attributed to changing well characteristics or pump characteristics. Operational Array Capacity Utilization of 44 percent indicates that the pump system was not utilized to its full potential. FAT Array Capacity Utilization of 92 percent versus an operational Array Capacity Utilization of 44 percent support the possibility of changing well or water meter characteristics.

Comparing design parameters to performance data show that the daily, FAT and FIT, data and design parameters have comparable volume of water pumped per energy (kW-hr) rates.

Table 6-3 lists performance data for the Nyali water system. Figure 6-9 shows cumulative water pumped, and graphs volume of water pumped, and pump run-time over the 16-month period. Figure 6-10 graphs array AH versus time; Figure 6-11 shows array AH versus volume of water pumped; and Figure 6-12 graphs insolation versus volume of water pumped. Figure 6-13 graphs pump run-time versus volume of water pumped.

Operational data shows little comparison to design parameters, mostly caused by the villagers not utilizing the system to its capacity, and possible problems with the accuracy of the water meter. A missionary in the village reported that the operator shut off the system at times to stop what he considered excessive water use by birck makers.

Table 6-3. Nyali Water System Performance Data

	Design Parameters	Final Acceptance Data (FAT) 2/4/85	Operational Data Low-High	Final Inspection Data (FIT) 2/25/86
Insolation ($kW-HR/M^2$)	4.16	3.34	4.68	2.1
Potential Array Output (amp-hours/day)	57	46	65	29
Actual Array Output (amp-hours/day)	NA	42.2	28.6	23.5
Array Capacity Utilization (percent)	NA	92	44	81
M^3/day	5.4	4.9	2.67	2.3
Run-time/day (hours/day)	NA	2.9	4.8-8.4	4.7
Insolation $M^3/kW-HR/M^2$	1.3	1.47	0.55	1.10
M^3/Hour	NA	1.69	0.29-0.56	0.49
M^3/Ampere-HR	NA	0.12	0.10	0.10

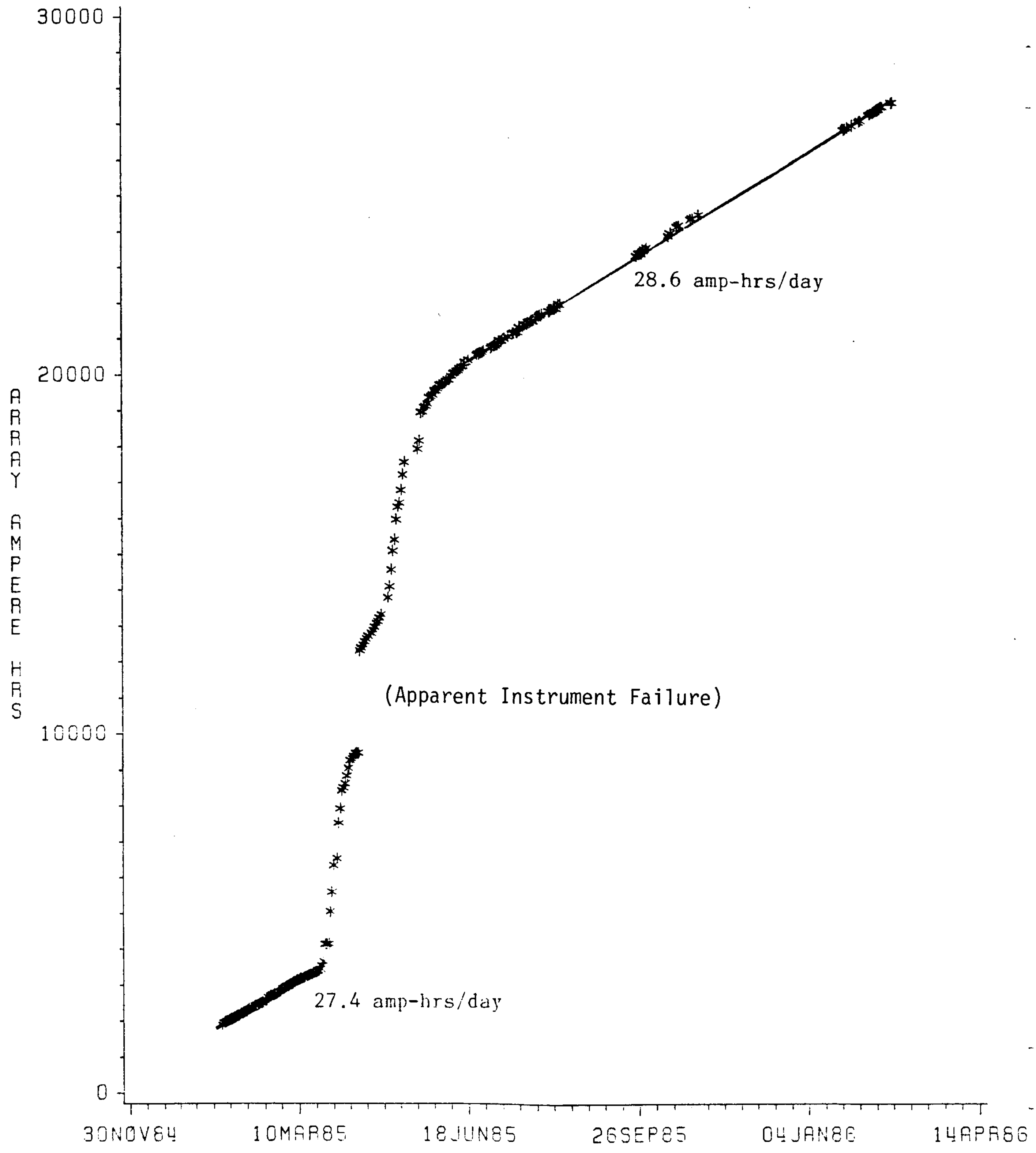
FI=Failed Instrument
ID=Insufficent Data
NA=Not Applicable

Note: FAT & FIT pump performance data presented are instantaneous values, not daily readings.

FIGURE 6-9

NYALI DATA

WATER PUMPING DATA
ARRAY AMPERE HRS. VS. DATE



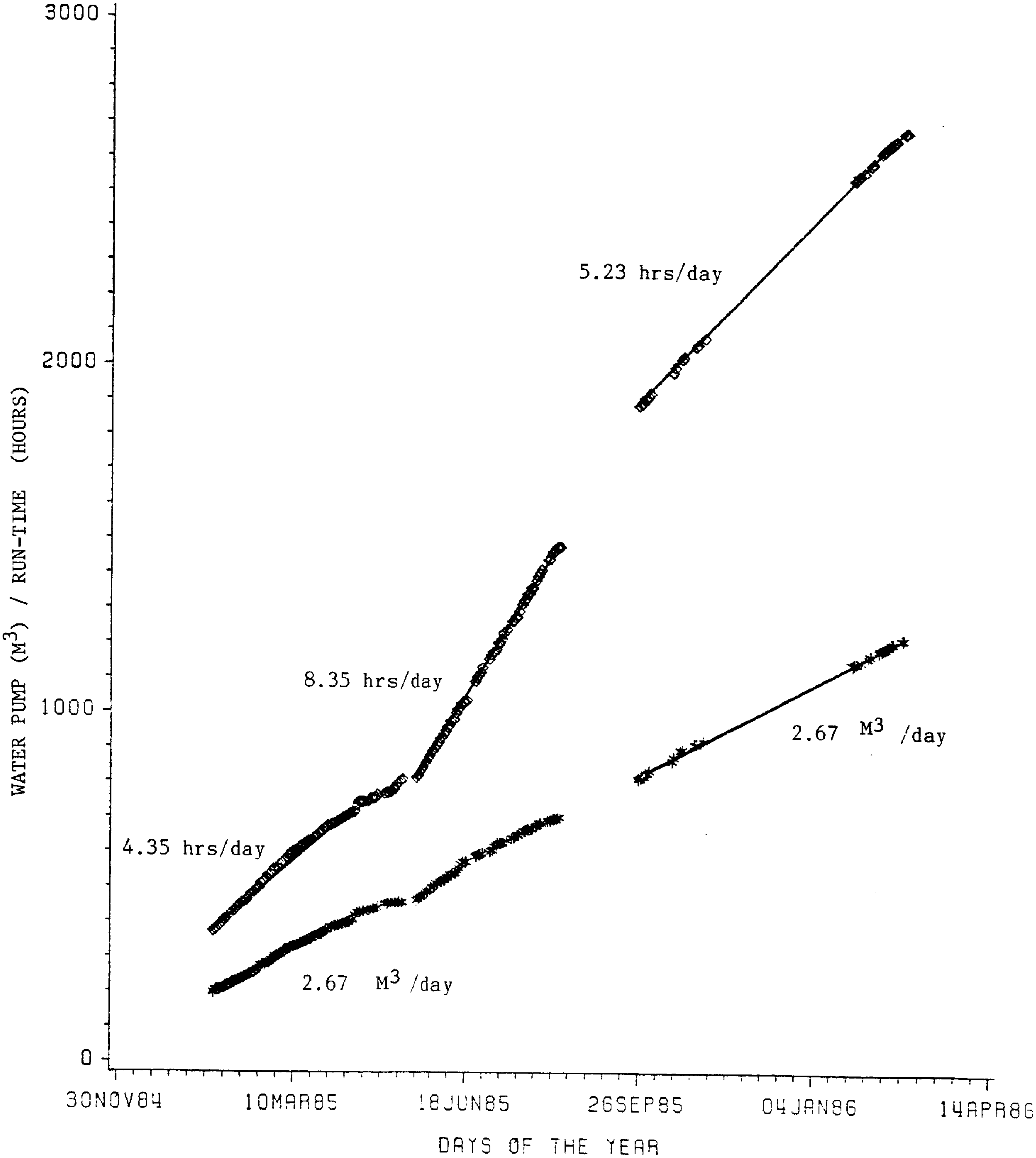
AS OF FEBRUARY 4, 1986

FIGURE 6-10

NYALI DATA

WATER PUMPING DATA

M^3, HRS VS. DATE



STAR: VOLUME OF WATER PUMPED

DIAMOND: HOURS OF PUMP OPERATION

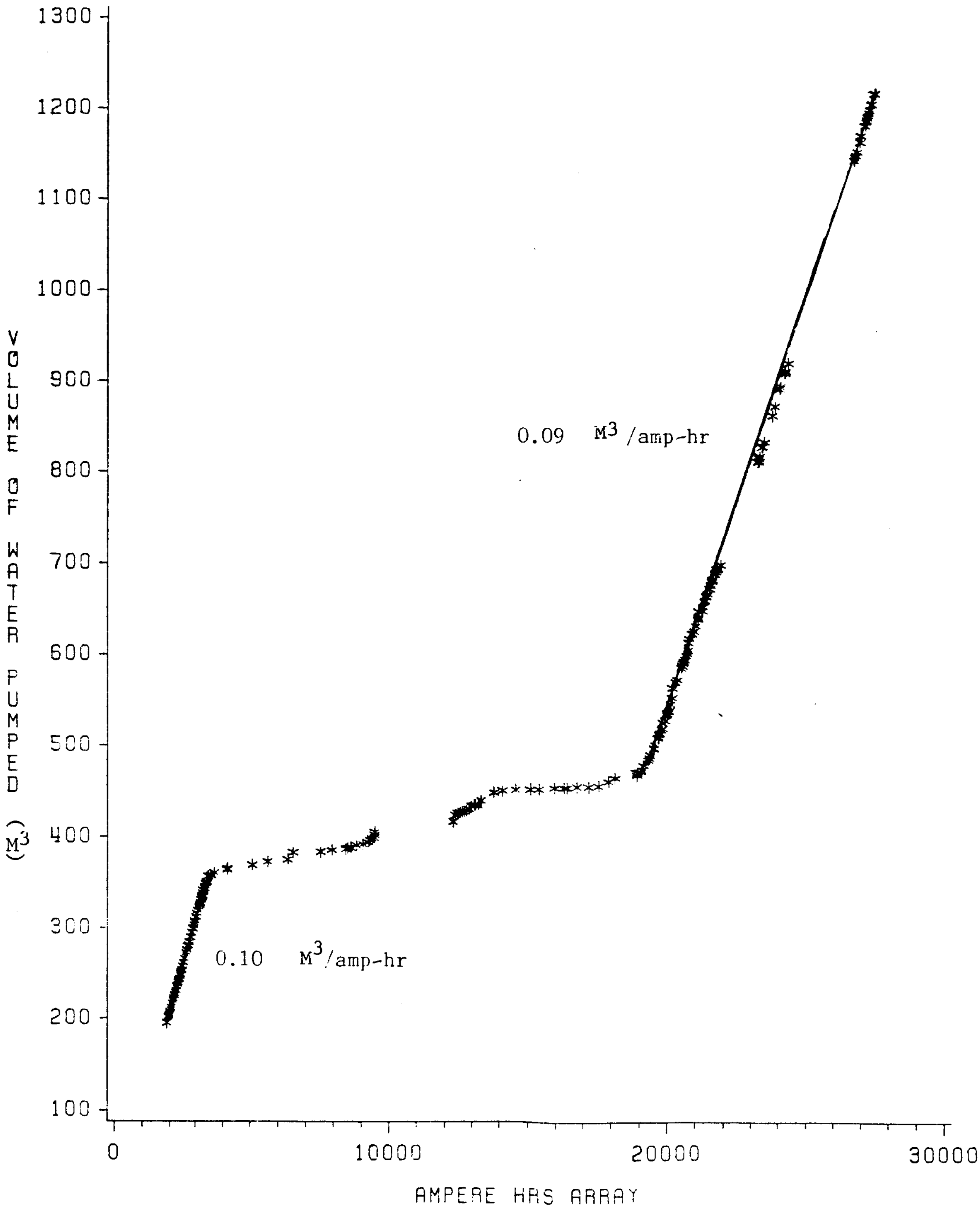
AS OF APRIL 4, 1986

FIGURE 6-11

NYALI DATA

WATER PUMPING DATA

M^3 WATER VS. ARRAY AMPERE HOURS



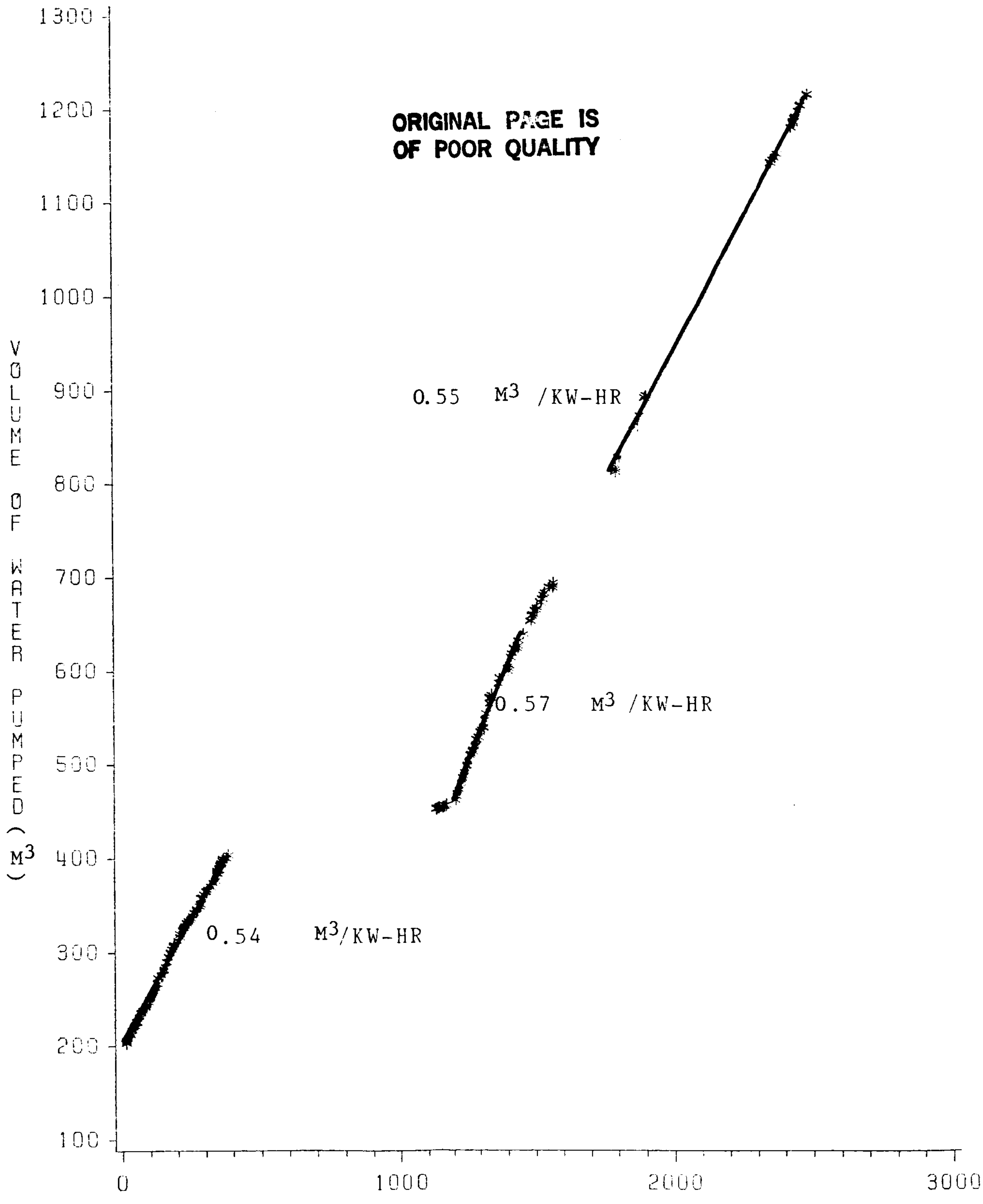
AS OF APRIL 4,1986

FIGUE 6-12

NYALI DATA

WATER PUMPING DATA

WATER PUMPED M^3 VS INSOLATION (KW-HR)



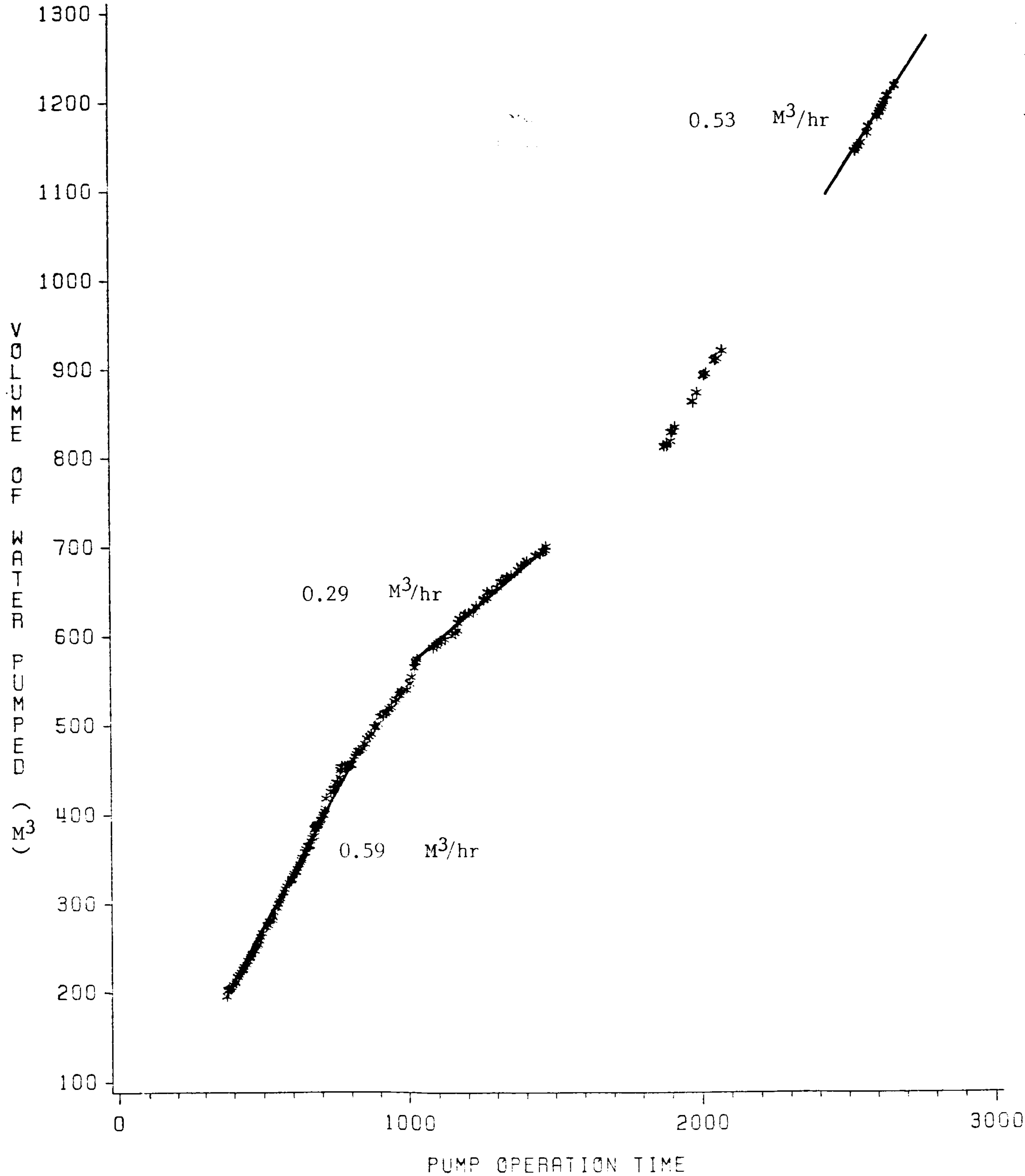
AS OF APRIL 14, 1980

FIGURE 6-13

NYALI DATA

WATER PUMPING DATA

M^3 WATER VS. PUMP OP TIME (HOURS)



AS OF APRIL 4, 1986

6.1.4 Onguia Water System

The Onguia water system had various problems during its first year of operation: the pump motor failed in late 1985, the run-time meter did not operate, the water meter malfunctioned in July 1985, and the data collection was sparse throughout the year. The pump motor and the meters were replaced during the FIT visit, but the sparse data give an incomplete indication of the system's performance. When operating, the system supplied all the water required by the village. The villagers have objected to the metallic taste of the water, but this is characteristic of the ground water in the area.

FAT and the limited yearly data show some correlation, but have discrepancies in volume of water pumped versus insolation, and in volume of water pumped versus ampere-hour. These rates should remain constant unless the system performance changes; therefore, the system performance appears to have changed for an unexplainable reason. On February 21, 1986, the pump motor was replaced and instantaneous readings taken on the FAT and FIT visits show that the pump operation is roughly the same.

Comparing the design objectives to the system performance data shows that the system was not utilized as designed.

During the FAT, it was noticed that three of the modules had been broken by village children throwing rocks down on the array. These were not replaced until the FIT, because MERH wanted to observe the performance degradation of damaged modules. There was essentially no detectable degradation. The FIT measurements were taken after replacement of the modules.

Table 6-4 lists performance data for the Onguia water pump system. Figures 6-14 through 6-17 graph insolation, array current, volume of water pumped, and pump run-time for the system over the reporting period.

Table 6-4. Onguia Water System Performance Data

	Design Parameters	Final Acceptance Test Data (FAT) 1/28/85	Operational Data Low-High	Final Inspection Test Data (FIT) 2/22/86
Insolation ($kW\text{-}HR/M^2$)	4.16	3.3	4-6.1	4.2
Potential Array Output (amp-hours/day)	115	91	168	116
Actual Array Output (amp-hours/day)	NA	54.9	42.2	109
Array Capacity Utilization (percent)	NA	60	25	94
M^3/day	8.5	5.8	6.67	ID
Run-time/day (hours/day)	NA	FI	FI	FI
$M^3/kW\text{-}HR/M^2$	2.0	1.97	1.33	ID
M^3/Hour	NA	1.72	NA	1.84
M^3/Ampere-HR	NA	0.11	0.16	0.10

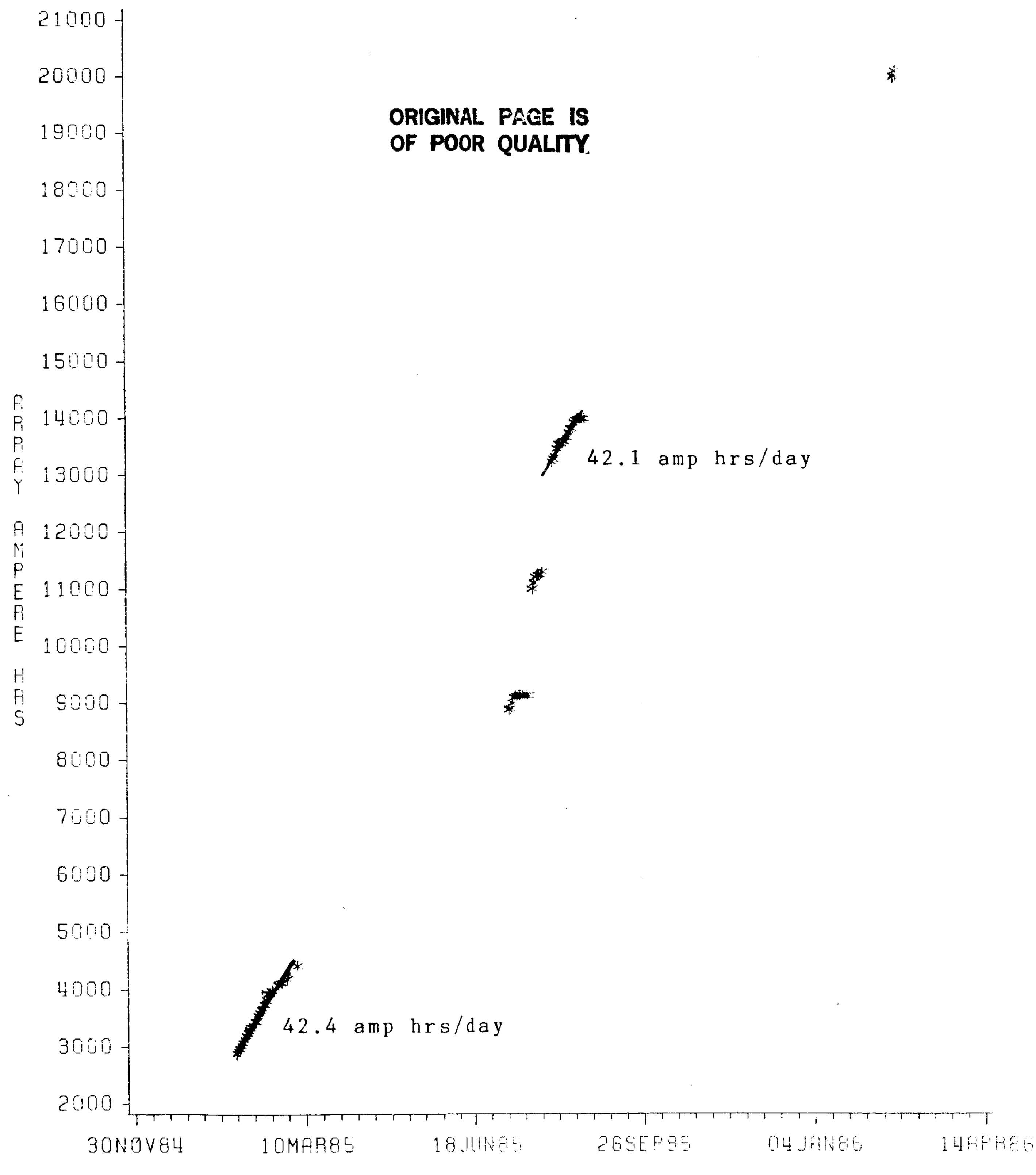
FI=Failed Instrument
ID=Insufficent Data
NA=Not Applicable

Note: FAT & FIT pump performance data presented are instantaneous values, not daily readings.

FIGURE 6-14

ONGUIA DATA

WATER PUMPING DATA
ARRAY AMPERE HRS. VS. DATE

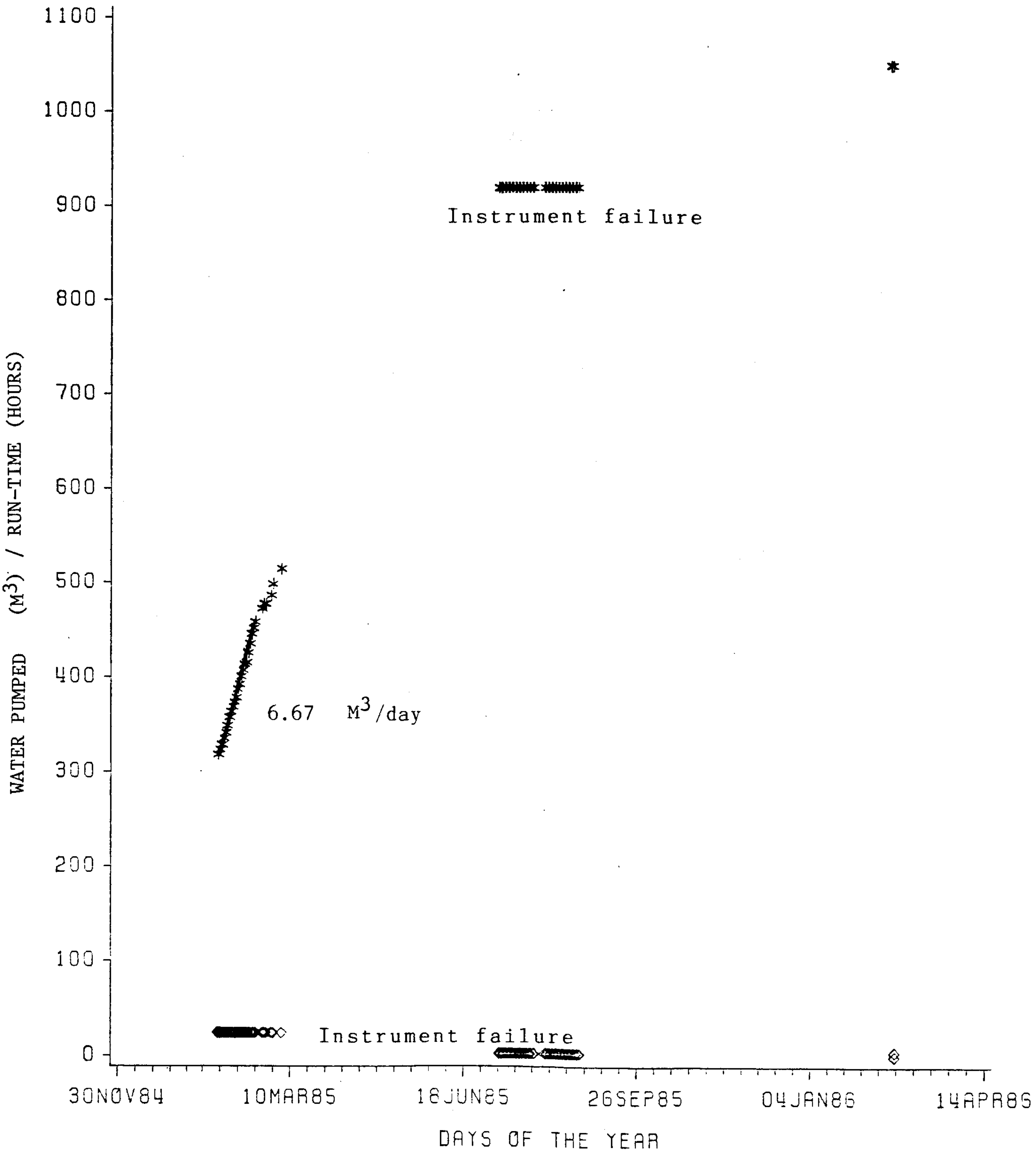


AS OF MAY 4, 1986

FIGURE 6-15

ONGUIA DATA

WATER PUMPING DATA
M^3, HRS VS. DATE



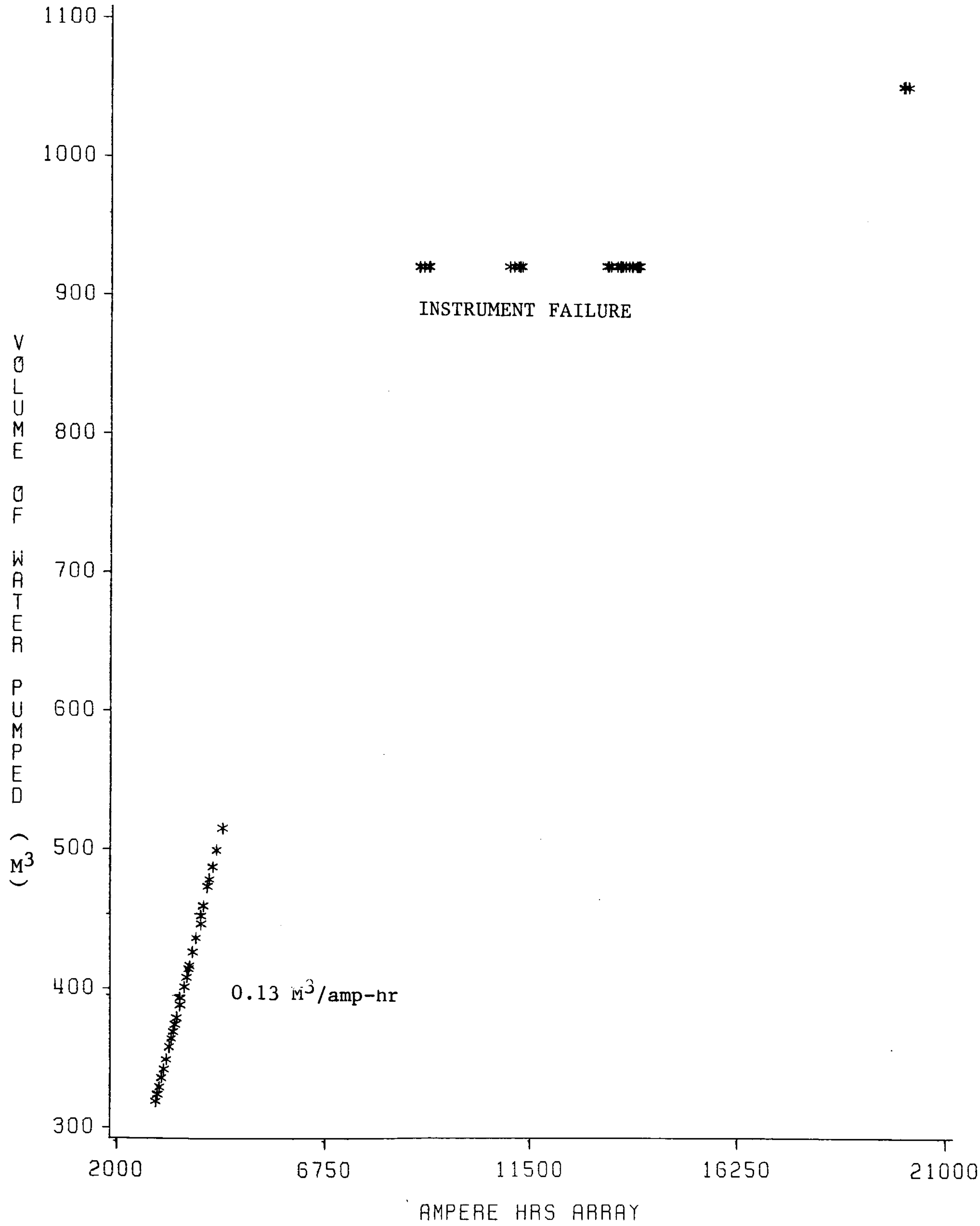
STAR: VOLUME OF WATER PUMPED
DIAMOND: HOURS OF PUMP OPERATION
AS OF APRIL 4, 1986

FIGURE 6-16

ONGUIA DATA

WATER PUMPING DATA

M^3 WATER VS. ARRAY AMP HRS



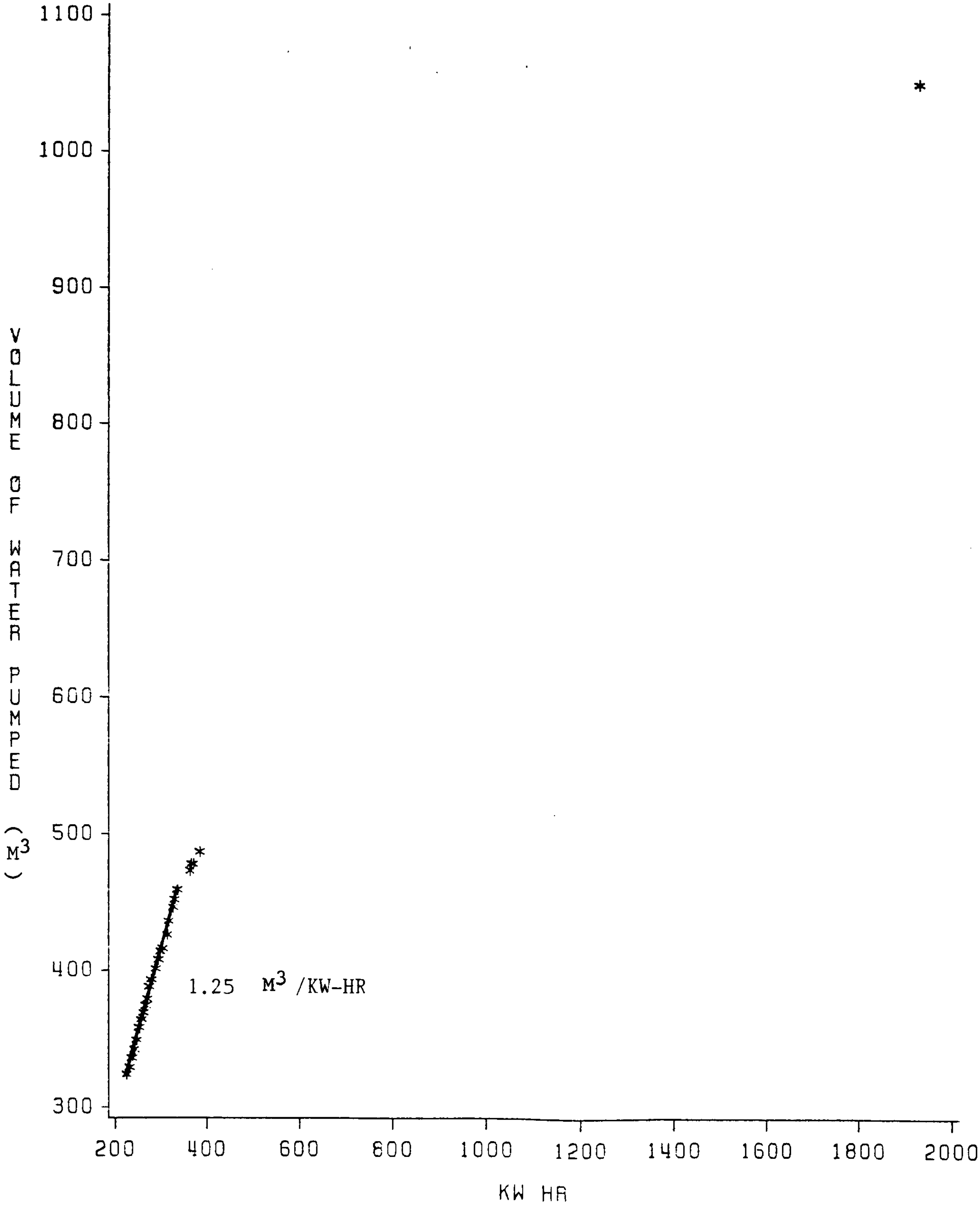
AS OF APRIL 4, 1986

FIGURE 6-12

ONGUIA DATA

WATER PUMPING DATA

M^3 WATER VS. INSOLATION KW-HR



AS OF APRIL 4,1986

6.2 Dispensaries

6.2.1 Bolossoville Dispensary System

During the first year of operation, the refrigerator was removed from service sometime in June 1985 due to continuous compressor operation and moved to Libreville. It was repaired by Solavolt during the FIT. The compressor electronic control module had failed in such a manner that the condenser fan did not operate. Without the condenser fan operating, the compressor operated continuously due to very poor heat removal from the condenser.

After the electronic control module was replaced, it was discovered that the compressor would not operate due to corrosion on the terminals of a circuit breaker that protects the refrigerator from reverse voltage. The corrosion was removed and the refrigerator operated properly.

Two failures within the instrumentation have limited the available data. Both the compressor run-time meter and the refrigerator ampere-hour meter failed late in the year.

The change in total system ampere-hour consumption of 27.4 ampere-hours per day before and after June 25, 1985 reflects R/F shutdown due to the problems noted above.

Refrigerator temperature data shows that the refrigerator maintained proper temperatures when operating. Transporting the refrigerator to and from Libreville caused failure of the freezer temperature probe. This was not repaired, since the estimated delivery time for parts exceeded the contract period.

It is difficult to compare the FAT and FIT data to the operational data, because the refrigerator was not cycling properly during the FAT and FIT visits. Prior to the FAT, the refrigerator had operated continuously, and had reached very low temperatures due to instrumentation cable wiring errors during installation. The refrigerator was still warming up during the FAT visit. During the FIT visit, the refrigerator had just been returned to the village and was still cooling down at the time the FIT team left Bolossoville. During the period that the refrigerator was operating normally, the operational data was consistant with the design parameters.

Use of the dispensary lights and fan was less than anticipated during the year, which was similar with the experience in the other villages.

Data analysis for the period during which the refrigerator operated properly shows that the PV array capacity utilization for the period was 25.5 percent, indicating a sufficient system design and under-utilization of the system.

Table 6-5 lists various performance data for the Bolossoville dispensary. Figures 6-18 through 6-20 graph array and load performance factors for the Bolossoville refrigerator system.

Table 6-5. Bolossoville Dispensary System Performance Data

	Design Parameters	Final Acceptance Test Data (FAT) 2/3/85	Operational Data Low-High	Final Inspection Test Data (FIT) 2/19/86
Insolation ($kW-HR/M^2$)	4.16	4.1	3.5-4.4	FI
Potential Array Output (amp-hours/day)	153	151	129-162	FI
Actual Array Output (amp-hours/day)	113.2	73.9	17.7-41.3	26.3
Array Capacity Utilization (percent)	73.8	48.9	17.7-41.3	FI
Total Load (amp-hours/day)	113.2	25.9	14.7-37.3	27.9
Refrigerator Load (amp-hours/day)	40	Note 1	27.3	Note 2
Other Loads (amp-hours/day)	73.2	25.8	14.4	Note 2
R/F Run-time (hours/day)	6.6	Note 1	6.62	Note 2
Fan Run-time (hours/day)	4	FI	FI	Note 2
Ambient Temperature (C)	30	28.5	18/37	Note 2
Refrigerator Temperature	0/8	-6.5	0/12	Note 2
Freezer Temperature	-5/-10	-22	-1/-30	Note 2

FI=Failed Instrument

Note 1: Due to an installation wiring error, the R/F compressor had operated continuously for two weeks prior to the FAT visit. The unit was still warming up during the FAT visit and did not need to operate.

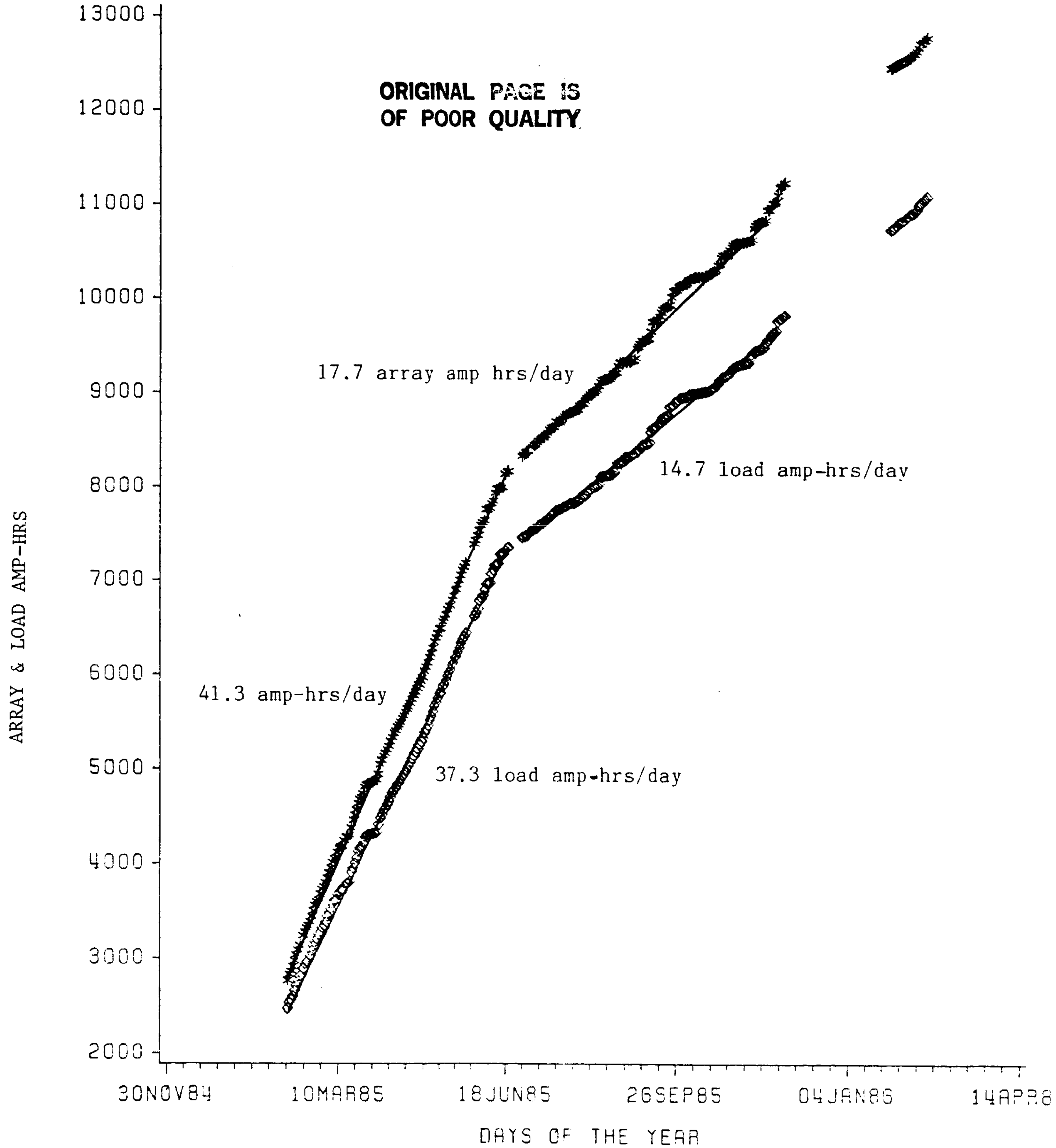
Note 2: Cooling down

FIGURE 6-18

BOLOSSOVILLE DATA

DISPENSARY DATA
ARRAY AMP HRS LOAD AMP HRS VS. DATE

ORIGINAL PAGE IS OF POOR QUALITY



STAR: AMPERE HOURS ARRAY
DIAMOND: AMPERE HOURS LOAD
AS OF MAY 4, 1986

FIGURE 6-19

BOLOSSOVILLE DATA

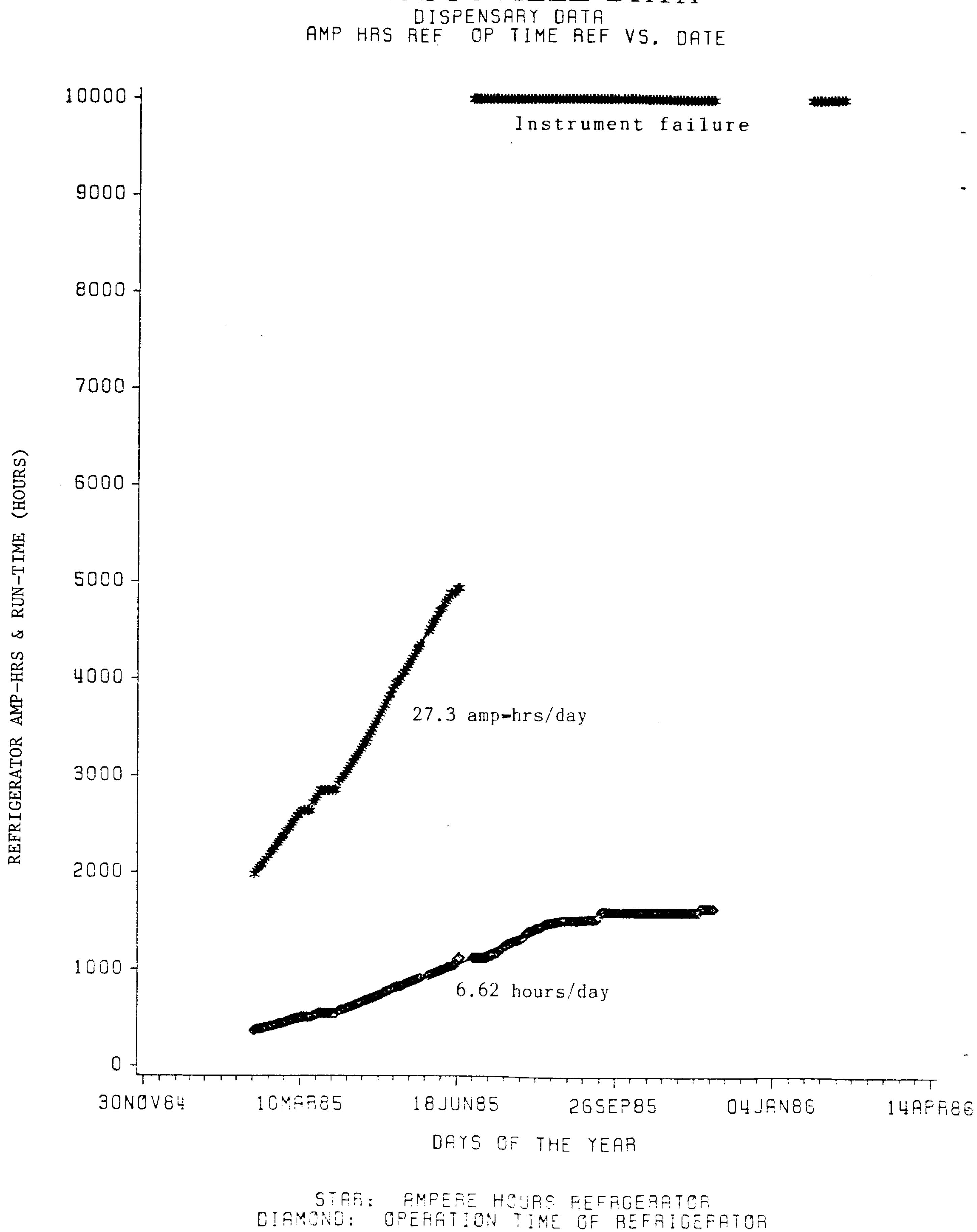
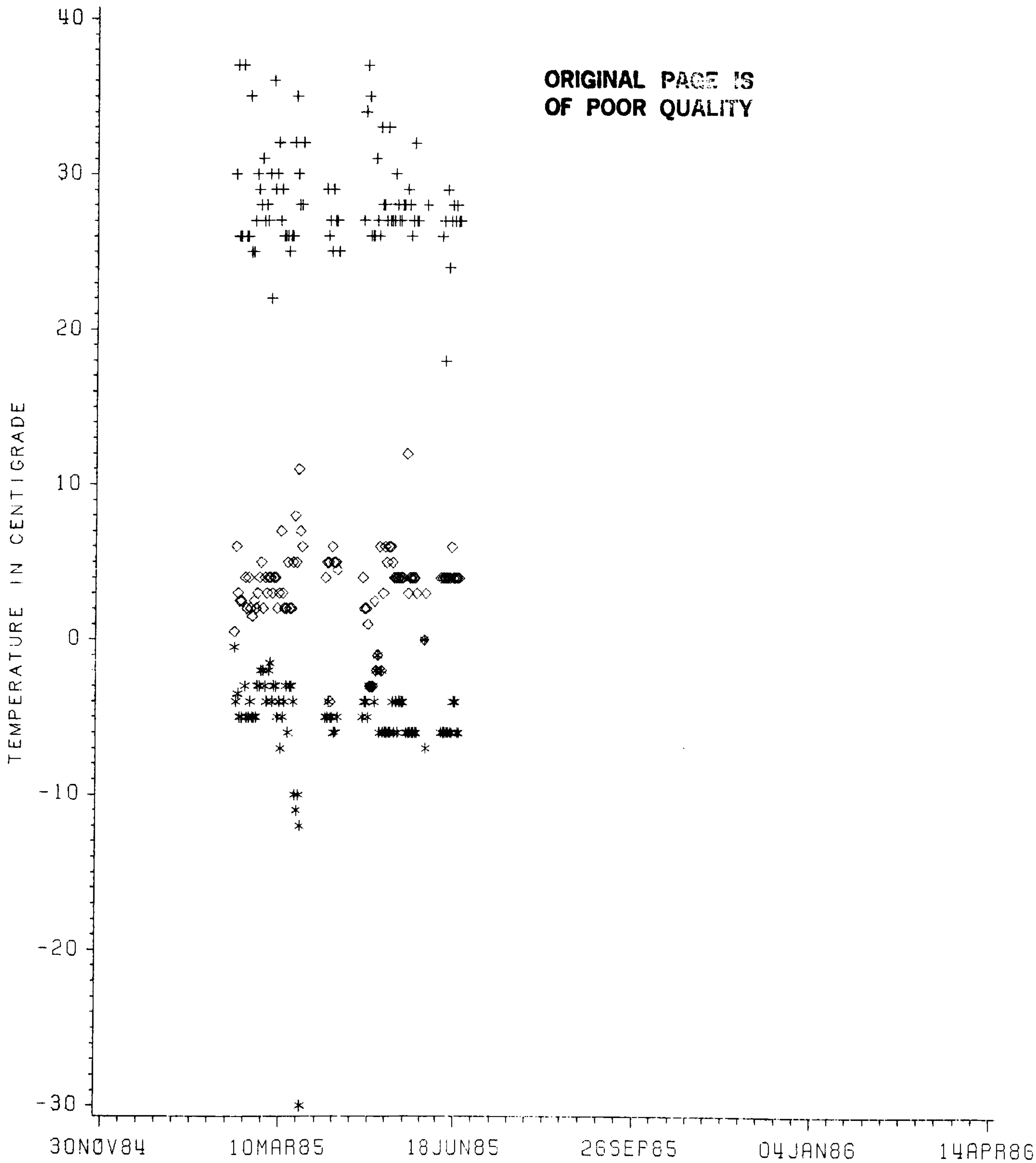


FIGURE 6-20

BOLOSSOVILLE

REFRIGERATOR TEMPERATURE PERFORMANCE



STAR: FREEZER TEMPERATURE
DIAMOND: REFRIGERATOR TEMPERATURE
PLUS: AMBIENT TEMPERATURE

6.2.2 Donguila Dispensary System

The Donguila dispensary system had various problems throughout its first year of operation. The instrumentation cable for the refrigerator and fan was shorted by rats chewing through the insulation. Shorting the cable, in turn, caused the failure of a transistor on the thermostat card which resulted in continuous compressor operation. As can be seen from the refrigerator temperature performance graph (Figure 6-23), the continuous compressor operation drove the R/F compartment temperature well below specifications. From the refrigerator performance graph (Figure 6-22), continuous compressor operation started approximately 19/5/85. During the period from 19/5/85 through 17/2/86, the refrigerator consumed roughly twice as many ampere-hours as predicted in the design.

Other system problems consisted of a failed load shed disconnect, battery charge regulator, and fan timer switch. During the FIT visit, all of these problems were corrected, and the system was returned to normal operation.

Data collection was fairly consistent throughout the year, but system malfunctions hampered analysis. FAT data for the array, load, and refrigerator ampere-hour figures correlated to the low operational data figures. The FIT data does not correlate with either the FAT or operational data. Data recorded from 2 January 1985 to 30 March 1985 showed the refrigerator consuming most of the array and load ampere-hours. Also during this period, the refrigerator run-time was 5.9 hours per day, 82 percent of the design value. By comparing design data to data recorded before the instrumentation short, it can be surmised that the dispensary's lights and ventilator were not being utilized as much as planned.

Table 6-6 shows performance data for the Donguila dispensary system. Figures 6-21 through 6-23 chart electrical performance, current consumption, and temperature of the Donguila refrigerator subsystem.

Table 6-6. Donguila Dispensary System Performance Data

	Design Parameters	Final Acceptance Test Data (FAT) 1/18/85	Operational Data Low-High	Final Inspection Test Data (FIT) 2/17/86
Insolation ($kW-HR/M^2$)	4.16	6.8	4.4-5.1	5.8
Potential Array Output (amp-hours/day)	153	250	162-188	213
Actual Array Output (amp-hours/day)	113.2	33.7	33.9-71.5	44.9
Array Capacity Utilization (percent)	73.8	14	21-38	21
Total Load (amp-hours/day)	113.2	31	33.3-101.5	70.6
Refrigerator Load (amp-hours/day)	40	29.4	29.7-95	66.8
Other Loads (amp-hours/day)	73.2	1.6	1.1-6.5	3.8
R/F Run-time (hours/day)	6.6	24	5.9-21.7	FI
Fan Run-time (hours/day)	4	5.8	0.5-FI	FI
Ambient Temperature (C)	30	37	24/34	35
Refrigerator Temperature	0/8	8.5	5/-10	14
Freezer Temperature	-5/-10	1	-4/-21	10

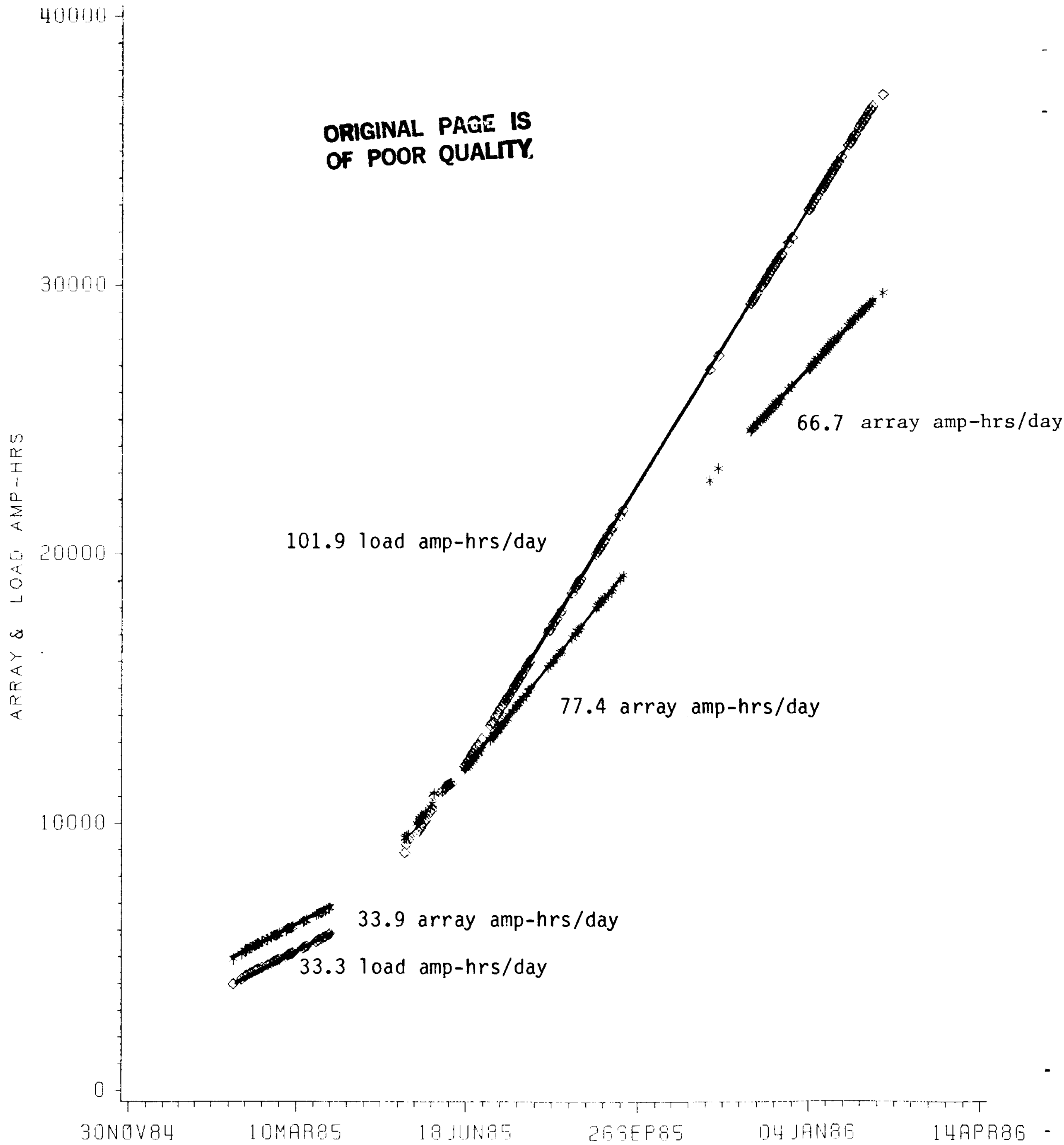
FI=Failed Instrument

FIGURE 6-21

DONGUILA

DISPENSARY

ARRAY AND LOAD PERFORMANCE

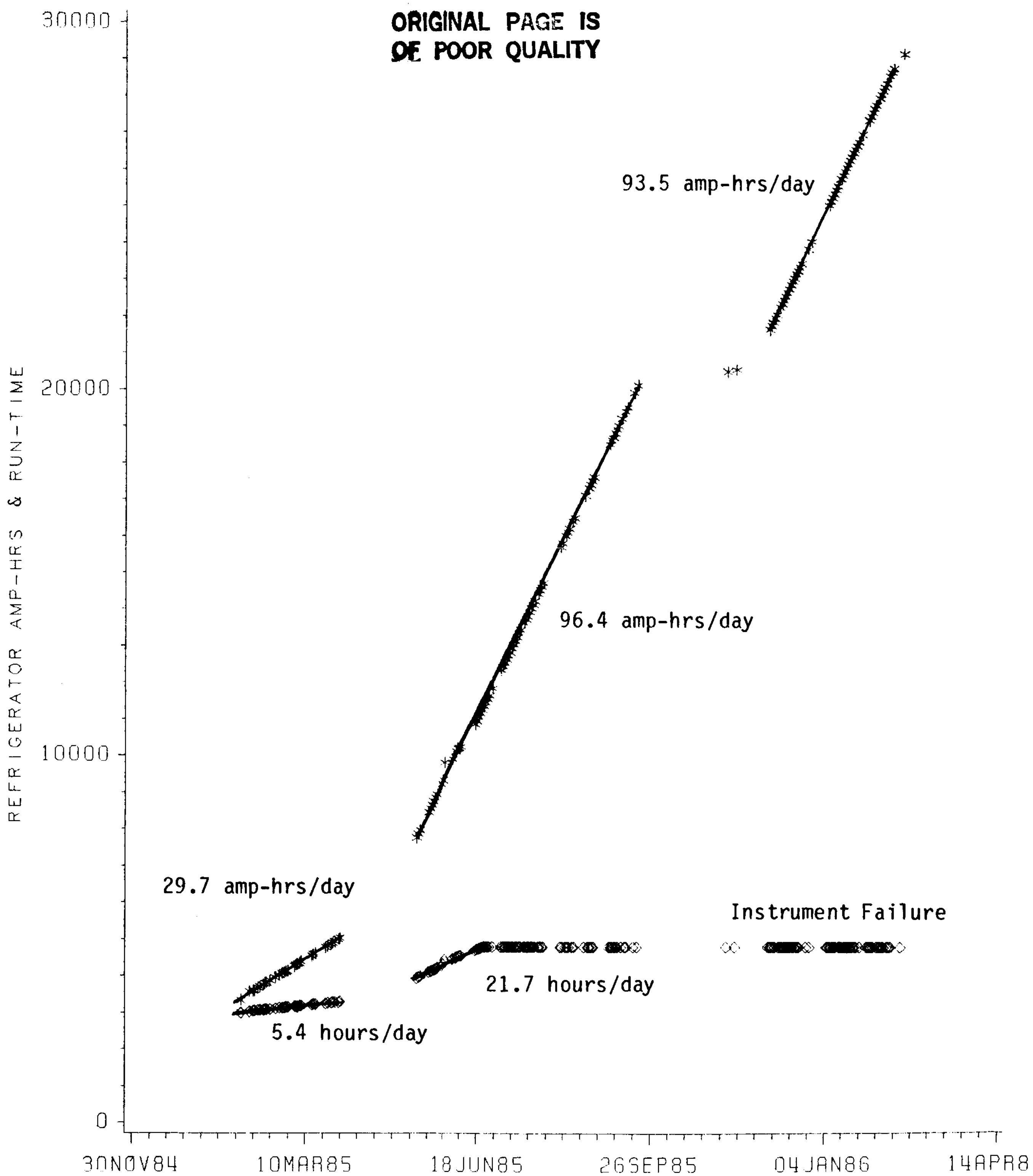


STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-22

DONGUILA

DISPENSARY
REFRIGERATOR PERFORMANCE

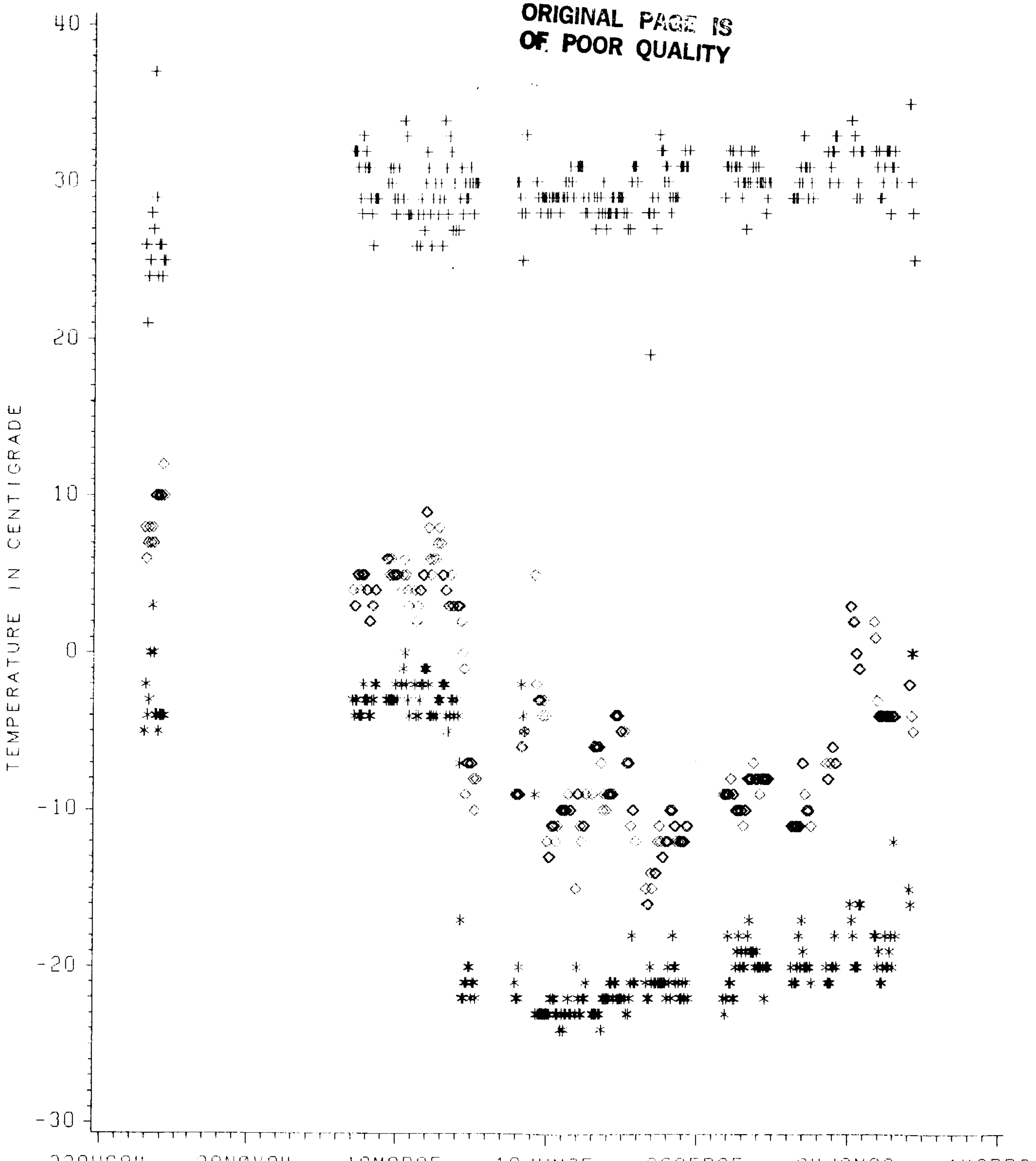


STAR: REFRIGERATOR AMPERE-HOURS
DIAMOND: REFRIGERATOR RUN-TIME

FIGURE 6-23

DONGUILA

REFRIGERATOR TEMPERATURE PERFORMANCE



STAR: FREEZER TEMPERATURE
DIAMOND: REFRIGERATOR TEMPERATURE
PLUS: AMBIENT TEMPERATURE

6.2.3 Nyali Dispensary System

The Nyali dispensary system functioned with only minor problems during its first year of operation. The maintenance performed during the FIT visit consisted of repairing a load ampere-hour meter and the insolometer, adjusting system-protection voltages, and replacing a timer switch with a conventional switch. Data collected throughout the year was mostly complete from January through July 1985, but was inconsistent from August 1985 to January 1986. The Nyali school system was not installed, because the school was deemed an unsuitable structure by the MERH. The insolometer for Nyali was therefore, installed on the dispensary PV system and the insolometer recorder replaced the refrigerator amp-hour meter in the instrumentation enclosure. This modification was made because insolation data was deemed more important than the refrigerator data.

The refrigerator temperature data (Figure 6-26) indicates that the refrigerator operated within proper temperature ranges.

Several operational parameters differ from the design objectives in a way that indicates that the system was not utilized to the extent to which it was designed. The refrigerator temperatures and R/F run-time were consistently within design parameters, leading to the conclusion that the lights and fan were not used to their design potential. The measured load was 44 percent of the design load; and based on the insolation measurements, the array capacity utilization was 33 percent. This also indicates that they system was not utilized to its full potential.

It was separately reported by an American missionary who lives in the village that the lights in the dispensary were kept on all night for the first part of the year.

Table 6-7 shows performance data for the Nyali dispensary. Figures 6-24 through 6-26 chart relevant system performance parameters for the Nyali refrigerator/freezer system.

Table 6-7. Nyali Dispensary System Performance Data

	Design Parameters	Final Acceptance Test Data (FAT) 1/18/85	Operational Data Low-High	Final Inspection Test Data (FIT) 2/17/86
Insolation ($kW-HR/M^2$)	4.16	3.34	4.68	2.1
Potential Array Output (amp-hours/day)	153	123	172	77
Array (amp-hours/day)	113.2	48.8	56.6	23.7
Array Utilization (percent)	73.8	40	33	31
Load (amp-hours/day)	113.2	43.9	55.2	FI
R/F Run-time (hours/day)	6.6	0.55	6.7	FI
Fan Run-time (hours/day)	4	5.26	FI	FI
Ambient Temperature (°C)	30	28.5	25	NA
Refrigerator Temperature (°C)	0/8	2	4	NA
Freezer Temperature (°C)	-5/-10	-8	-5	NA

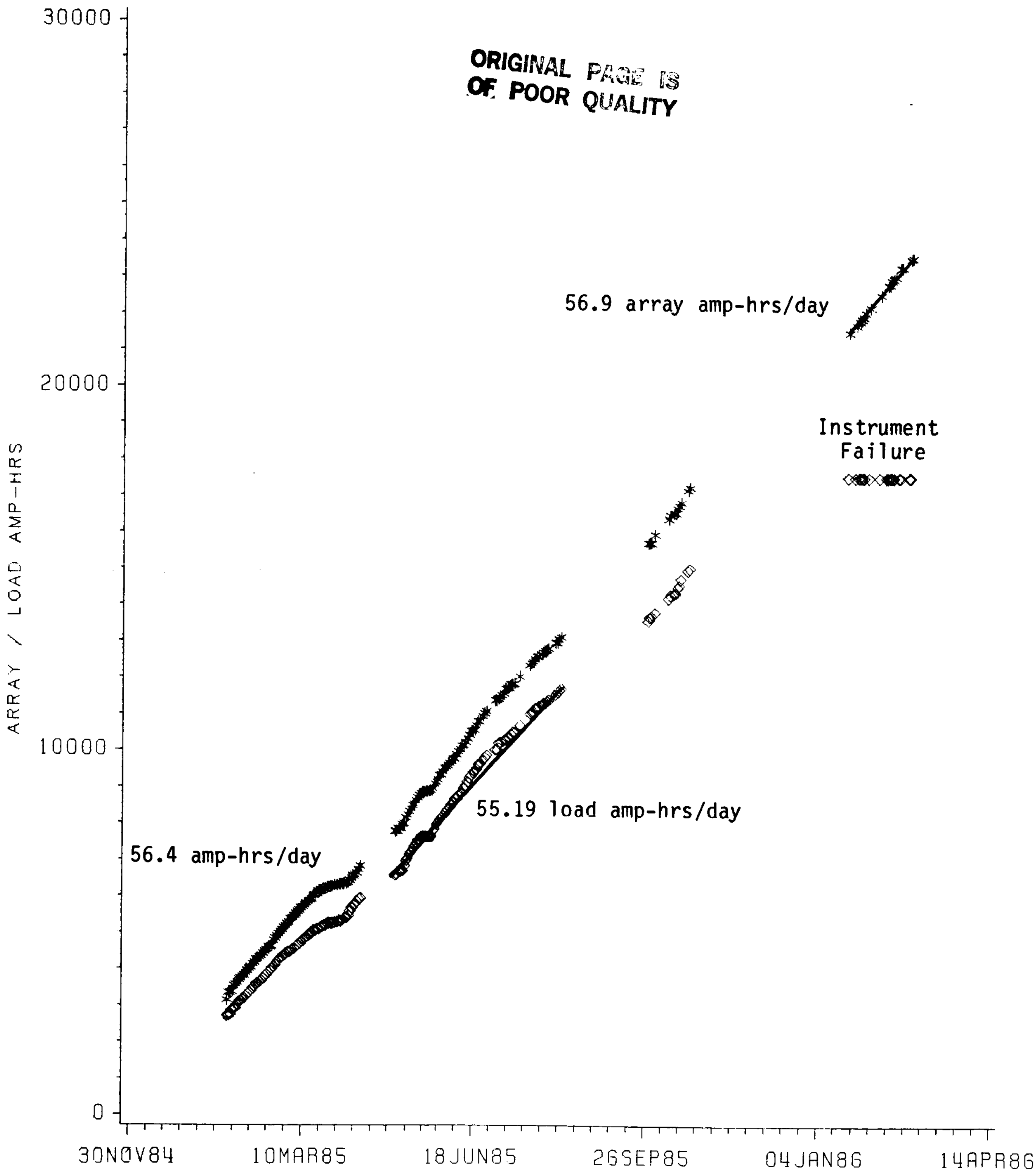
FI=Failed Instrument
NA=Not Applicable

FIGURE 6-24

NYALI

DISPENSARY

ARRAY AND LOAD PERFORMANCE



STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-25

NYALI

DISPENSARY

INSOLATION

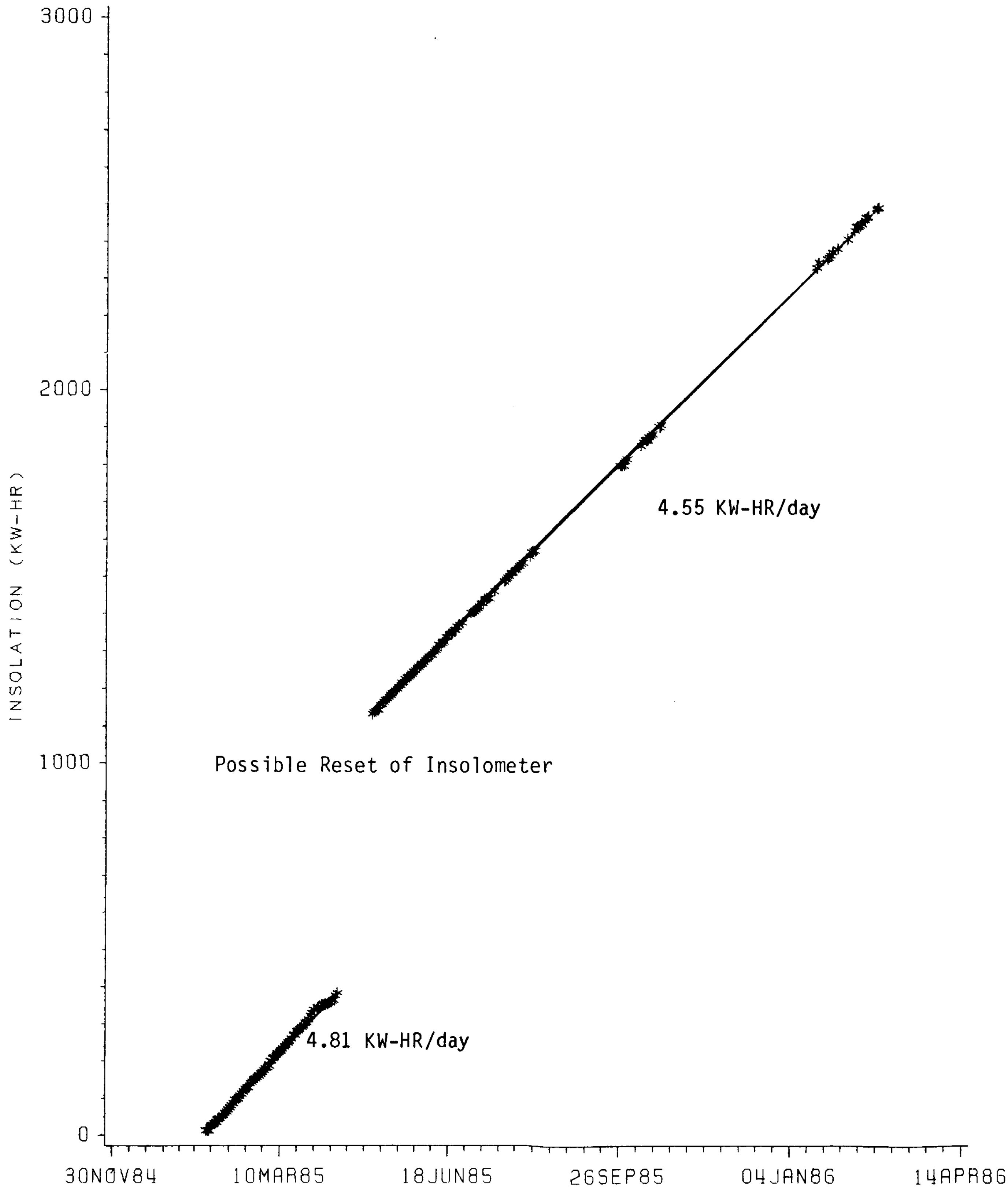
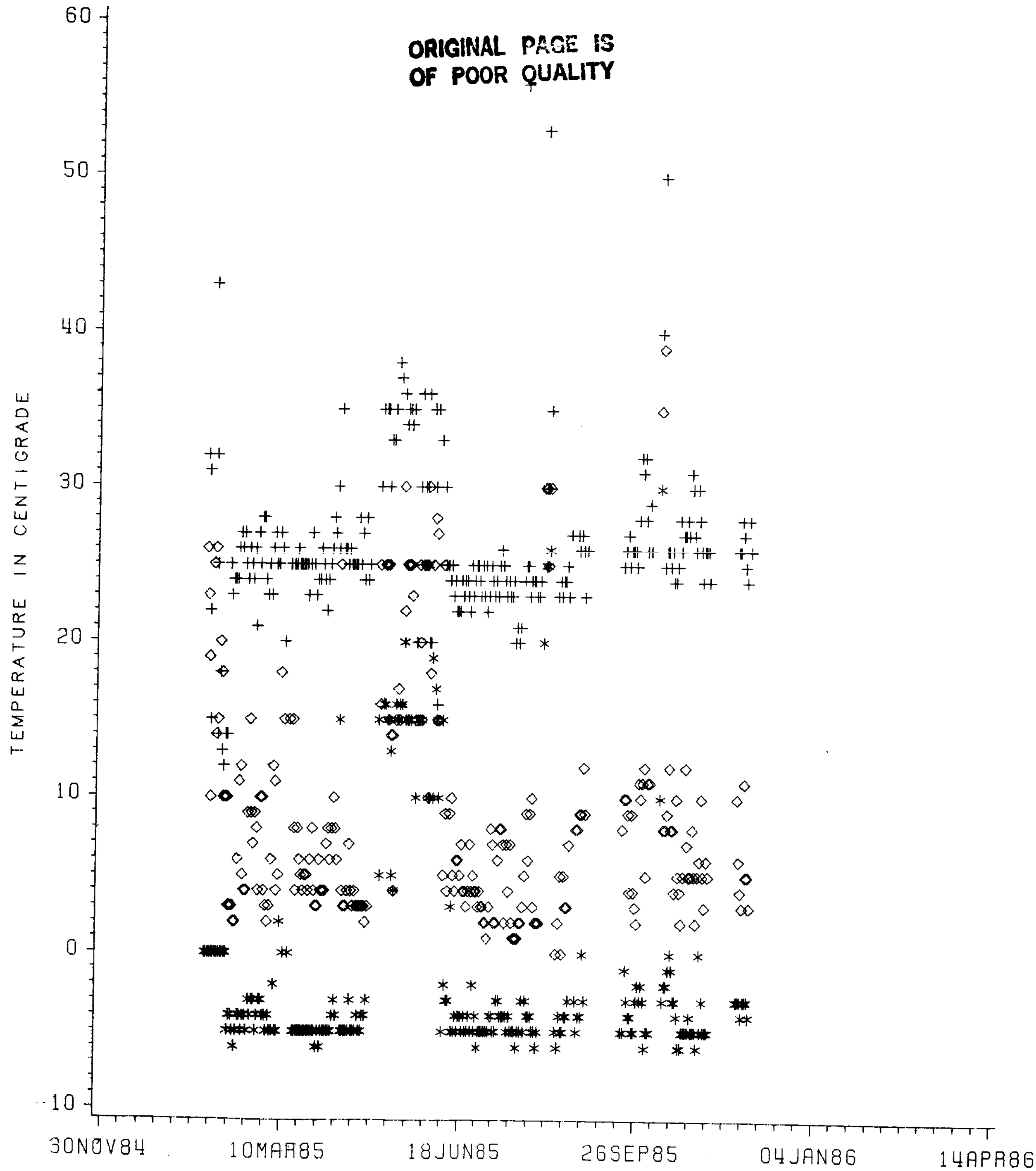


FIGURE 6-26

NYALI

REFRIGERATOR TEMPERATURE PERFORMANCE



STAR: FREEZER TEMPERATURE
DIAMOND: REFRIGERATOR TEMPERATURE
PLUS: AMBIENT TEMPERATURE

6.2.4 Onguia Dispensary

The Onguia dispensary was not staffed during the year between the FAT and FIT visits. Data collection was, therefore, scattered and does not allow a good evaluation of the system's performance. At the FIT visit, the refrigerator was not functioning and was found to have a failed compressor electronic module. Other problems with the system included a malfunctioned fan, run-time meter and a fluorescent light fixture. From the little data collected, the system appears to have otherwise functioned properly.

The FAT and yearly data show two different modes of operation for the system. During the day the FAT data was collected, the refrigerator was in a pull-down mode as can be seen by the large consumption of load ampere-hours, refrigerator ampere-hours, and that the R/F temperatures had not yet reached the normal operating ranges.

Comparing design objectives to performance data shows that the system was working at its maximum during the FAT data-collecting period and operated at less than the expected load during the year.

Table 6-8 shows performance data for the Onguia dispensary. Figures 6-27 through 6-29 chart array/load performance, refrigerator/freezer performance, and refrigerator/freezer temperature, respectively.

Table 6-8. Onguia Dispensary Performance Data

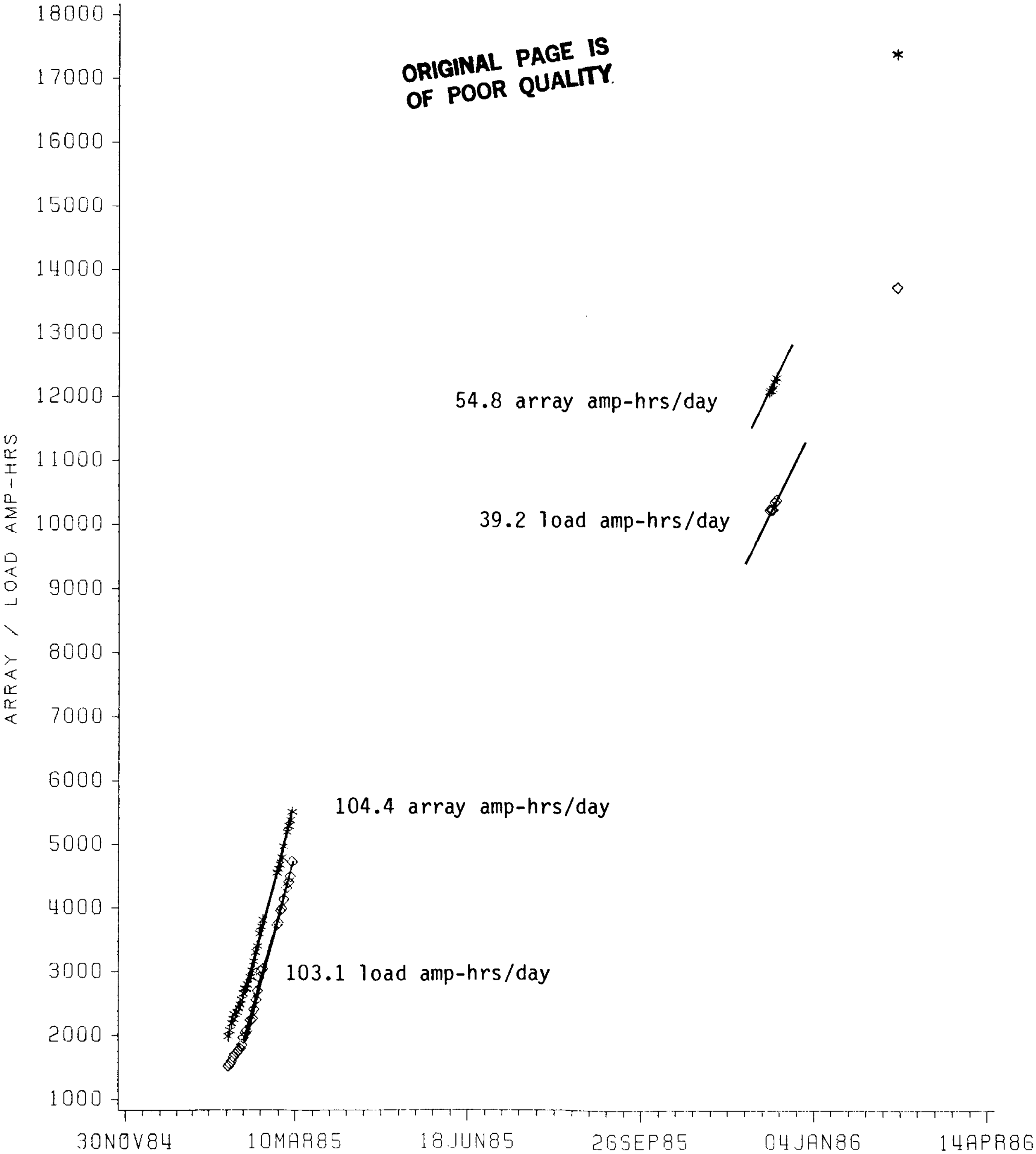
	Design Parameters	Final Acceptance Test Data (FAT) 1/27/85	Yearly Data Low-High	Final Inspection Test Data (FIT) 2/22/86
Insolation ($kW-HR/M^2$)	4.16	3.3	4-6.1	ID
Potential Array Output (amp-hours/day)	153	121	146-225	NA
Actual Array Output (amp-hours/day)	113.2	94.8	54.8-104.3	ID
Array Capacity Utilization (percent)	73.8	78	37-46	NA
Total Load (amp-hours/day)	113.2	118.6	39.2-103.1	ID
Refrigerator Load (amp-hours/day)	40	81.2	23.9-27.1	ID
Other Loads (amp-hours/day)	73.2	37.4	15.3-76	ID
R/F Run-time (hours/day)	6.6	23.7	1.7-7.9	ID
Fan Run-time (hours/day)	4	1.8	IF	IF
Ambient Temperature (C)	30	34	26	ID
Refrigerator Temperature	0/8	17	3	ID
Freezer Temperature	-5/-10	7.6	-4	ID

IF=Instrument Failure
ID=Insufficient Data
NA=Not Applicable

FIGURE 6-27

ONGUIA

DISPENSARY
ARRAY AND LOAD PERFORMANCE

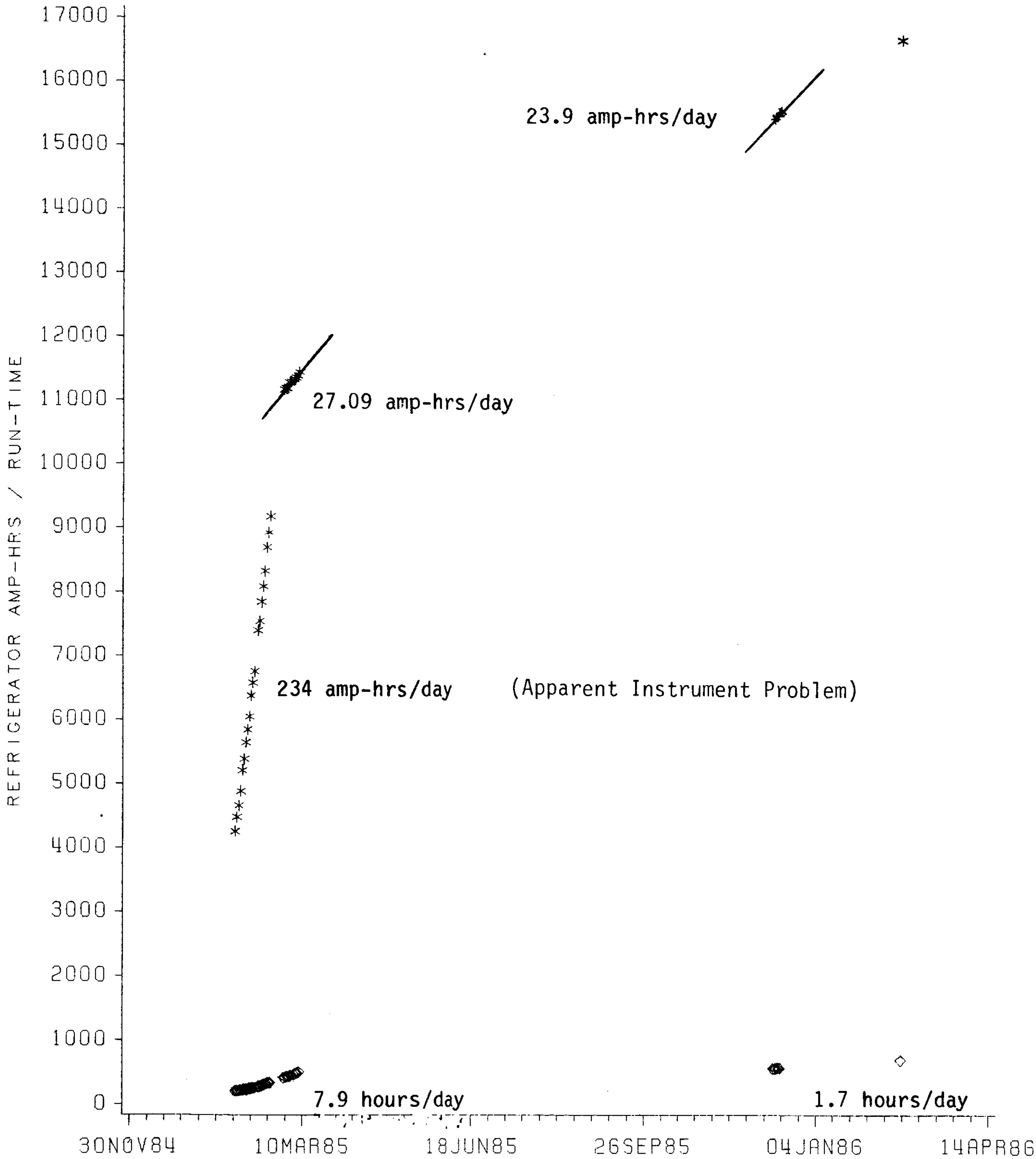


STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-28

ONGUIA

DISPENSARY
REFRIGERATOR PERFORMANCE

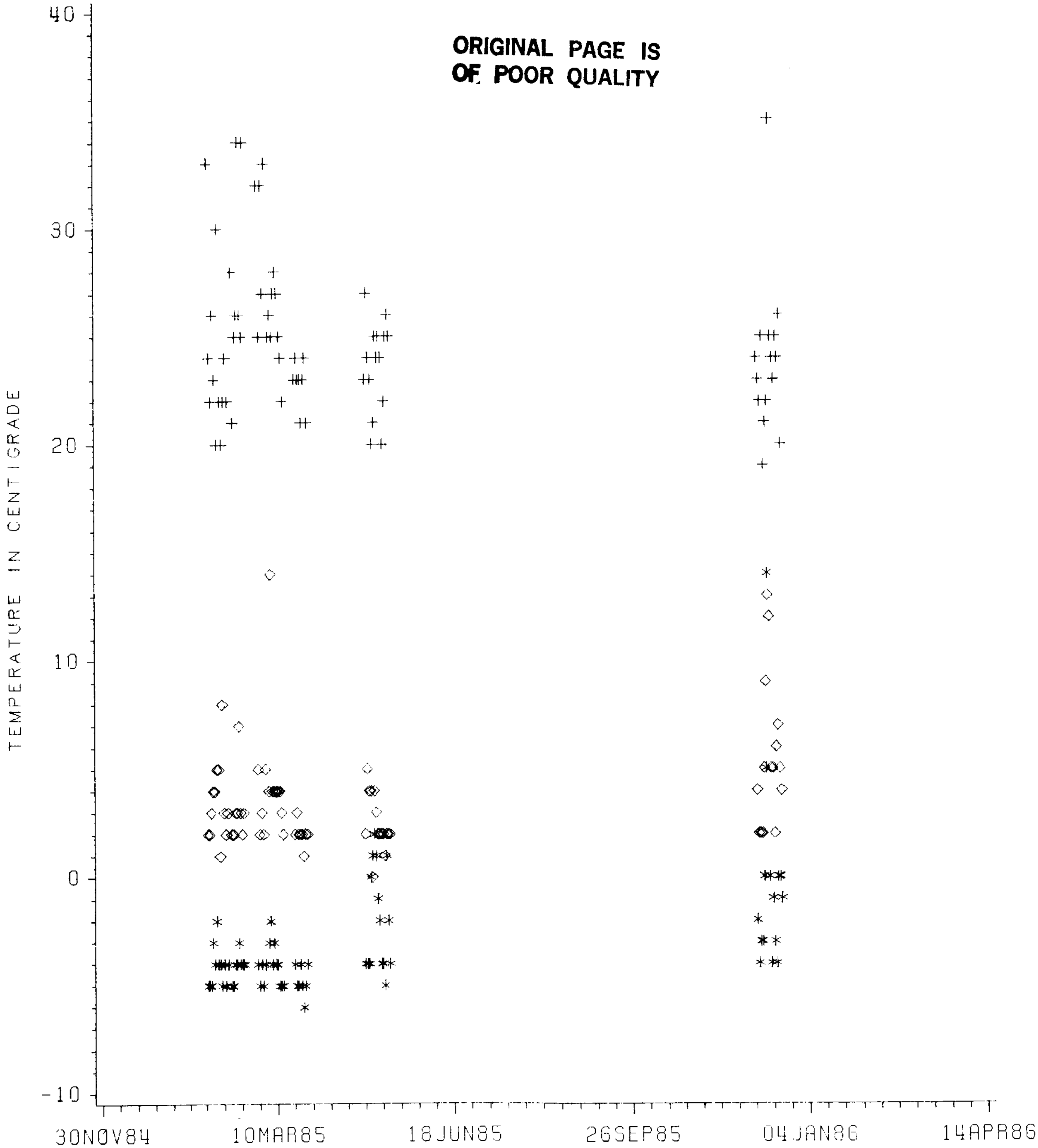


STAR: REFRIGERATOR AMPERE-HOURS
DIAMOND: REFRIGERATOR RUN-TIME

FIGURE 6-29

ONGUIA

REFRIGERATOR TEMPERATURE PERFORMANCE



STAR: FREEZER TEMPERATURE
DIAMOND: REFRIGERATOR TEMPERATURE
PLUS: AMBIENT TEMPERATURE

6.3 Schools

6.3.1 Bolossoville School

The Bolossoville school had some fluorescent light problems during the first year of operation and required only routine maintenance during the FIT visit. Several of the fluorescent light ballasts failed during the year, but no specific record was kept. Data collection throughout the year allowed a good evaluation of the system's performance. In September, 1985, the insolometer had problems with potentiometer was found to be open circuit during the February 1986 visit and was repaired. Later data sent to Solavolt by MFRH indicates that proper operator was restored.

FAT, yearly, and FIT data compare closely with FAT being on the low side of the yearly data and FIT data near the average values of the yearly data. The ampere-hours versus day graph (Figure 6-30) is representative of how the array output and load consumption can vary throughtout the year, being greatly dependent on the system usage. The graph of irradiance versus day (Figure 6-31) shows the irradiance was random throughout the year.

When comparing performance data (Table 6-4) to design objectives, the overestimate by the system design states that the system was not utilized as expected. Array utilization percentages also show that the system has a greater potential for use.

Table 6-9. Bolossoville School Performance Data

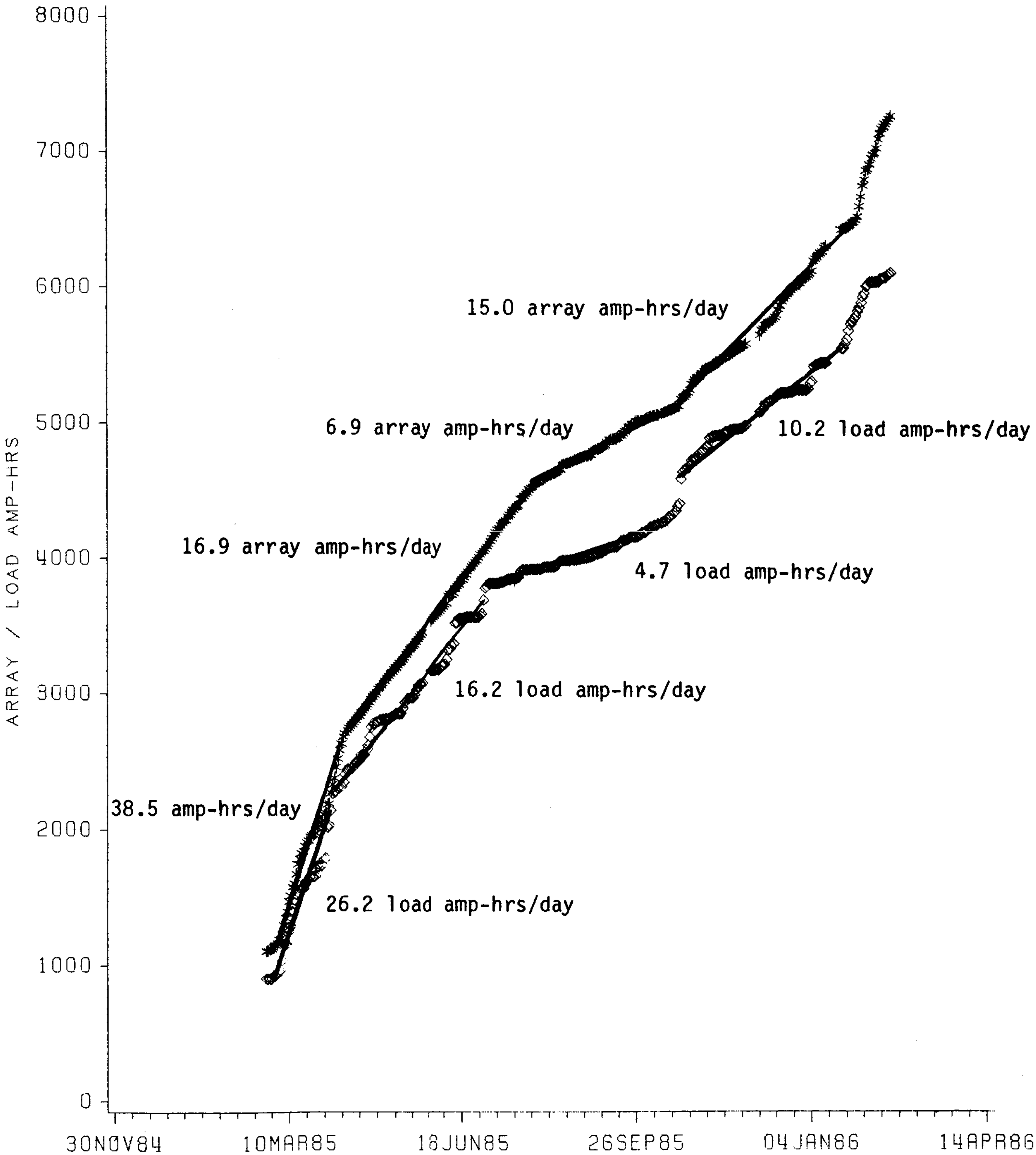
	Design Parameters	Final Acceptance Test Data (FAT) 2/03/85	Operational Data Low-High	Final Inspection Test Data (FIT) 2/19/86
Insolation ($kW-HR/M^2$)	4.16	4.1	3.5 4.4	IF
Potential Array Output (amp-hours/day)	77	75	64-81	NA
Array (amp-hours/day)	62	4.78	6.9-38.5	18.4
Array Utilization (percent)	81	7	11-48	NA
Load (amp-hours/day)	62	0.17	4.7-26.2	6.22

IF=Instrument Failure
NA=Not Applicable

FIGURE 6-30

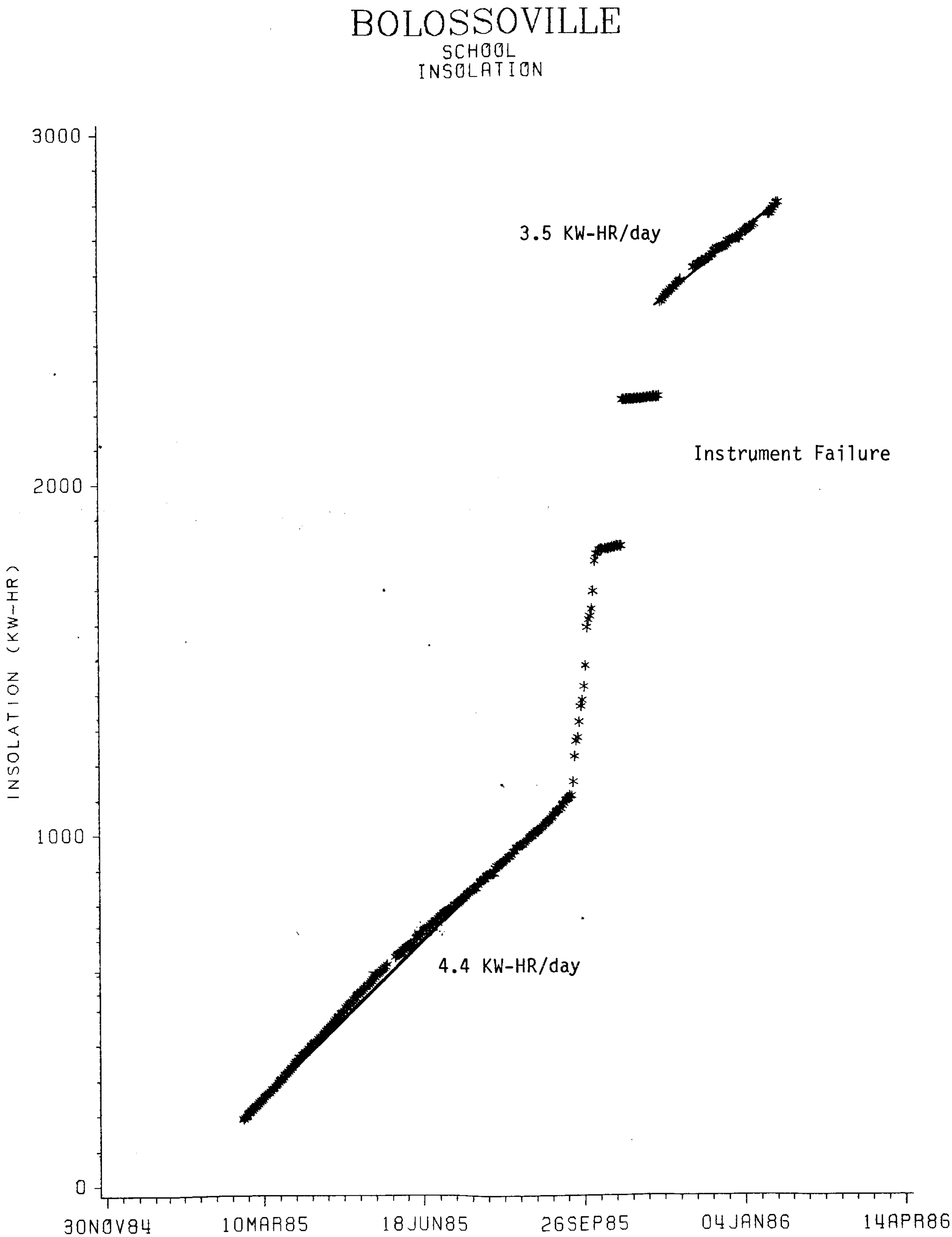
BOLOSSOVILLE

SCHOOL
ARRAY AND LOAD PERFORMANCE



STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-31



C-2

6.3.2 Donguila School

The PV system for the Donguila school has operated properly for the 18 months that it has been installed. There have been no problems in operating the lights, and television. During the FIT visit the VCR was found to be inoperative due to a tape jam. the VCR was repaired by CECA GADIS and returned to the village. All data indicates that the system is under-utilized.

It was reported in May, 1985, that the alarm was sounding, but none of the data indicates either a low or high voltage condition. During the FIT inspection, it was discovered that one of the voltage regulators had failed in a non-charging mode. It was replaced with a spare.

The school supervisor has been suggesting that two additional lights should be added to classrooms in an adjacent buildng and to the boy's dormitory over the classrooms in the main school building. The data indicates that there is adequate energy to support at least some additional loads.

Table 6-10 shows various performance data for the Donguila school system. Tables 6-32 and 6-33 graph array/load performance and site insolation, respectively.

Table 6-10. Donguila School Performance Data

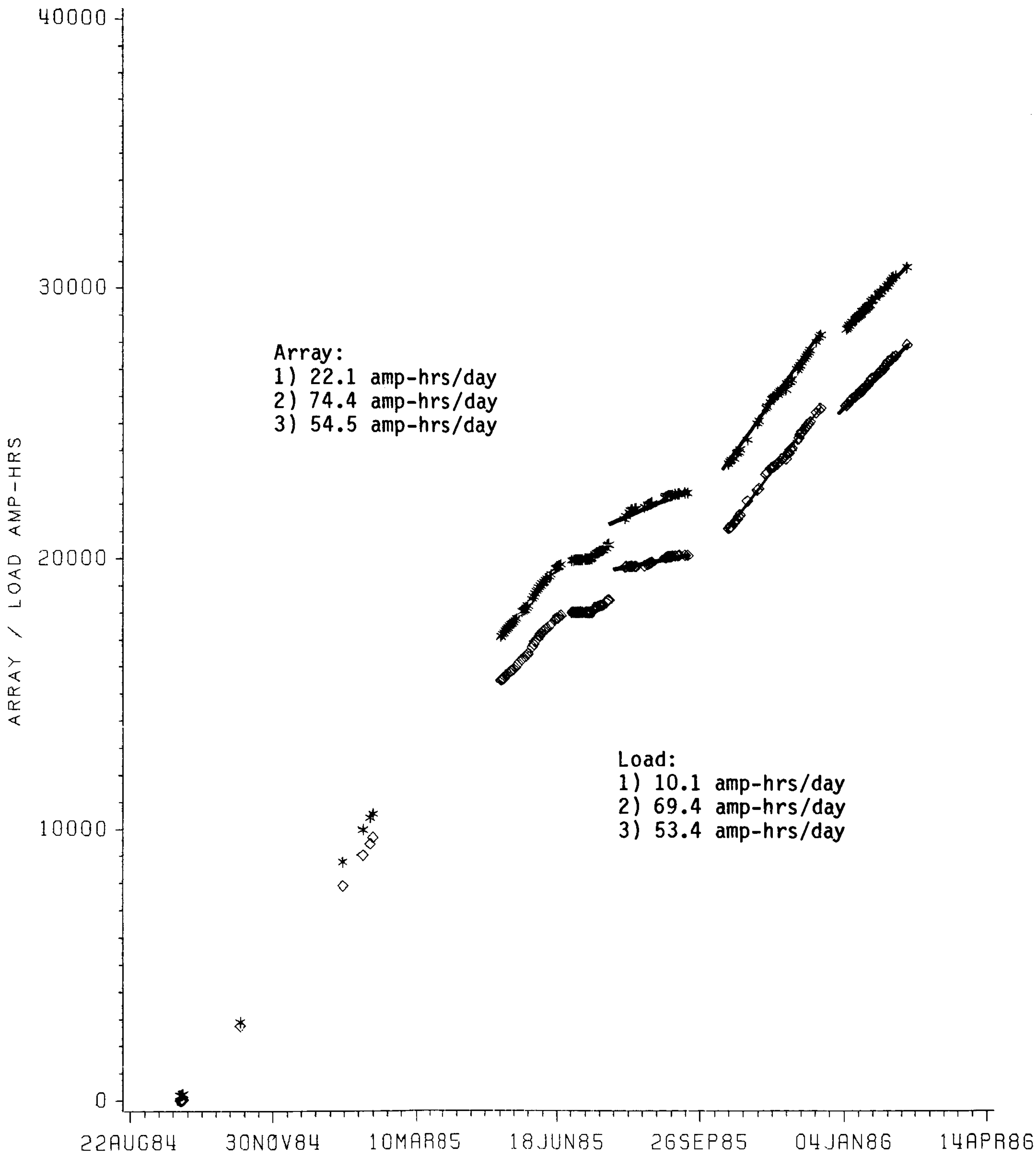
	Design Parameters	Final Acceptance Test Data (FAT) 1/18/85	Operational Data Low-High	Final Inspection Test Data (FIT) 2/17/86
Insolation ($kW\text{-}HR/M^2$)	4.16	4.78	4.4-5.1	5.73
Potential Array Output (amp-hours/day)	134	154	142-164	184.57
Array (amp-hours/day)	84	70.8	22.1-74.4	39.6
Array Utilization (percent)	63	46	15.6-45.4	21.5
Load (amp-hours/day)	84	117	10.1-69.4	50

FIGURE 6-32

DONGUILA

SCHOOL

ARRAY AND LOAD PERFORMANCE

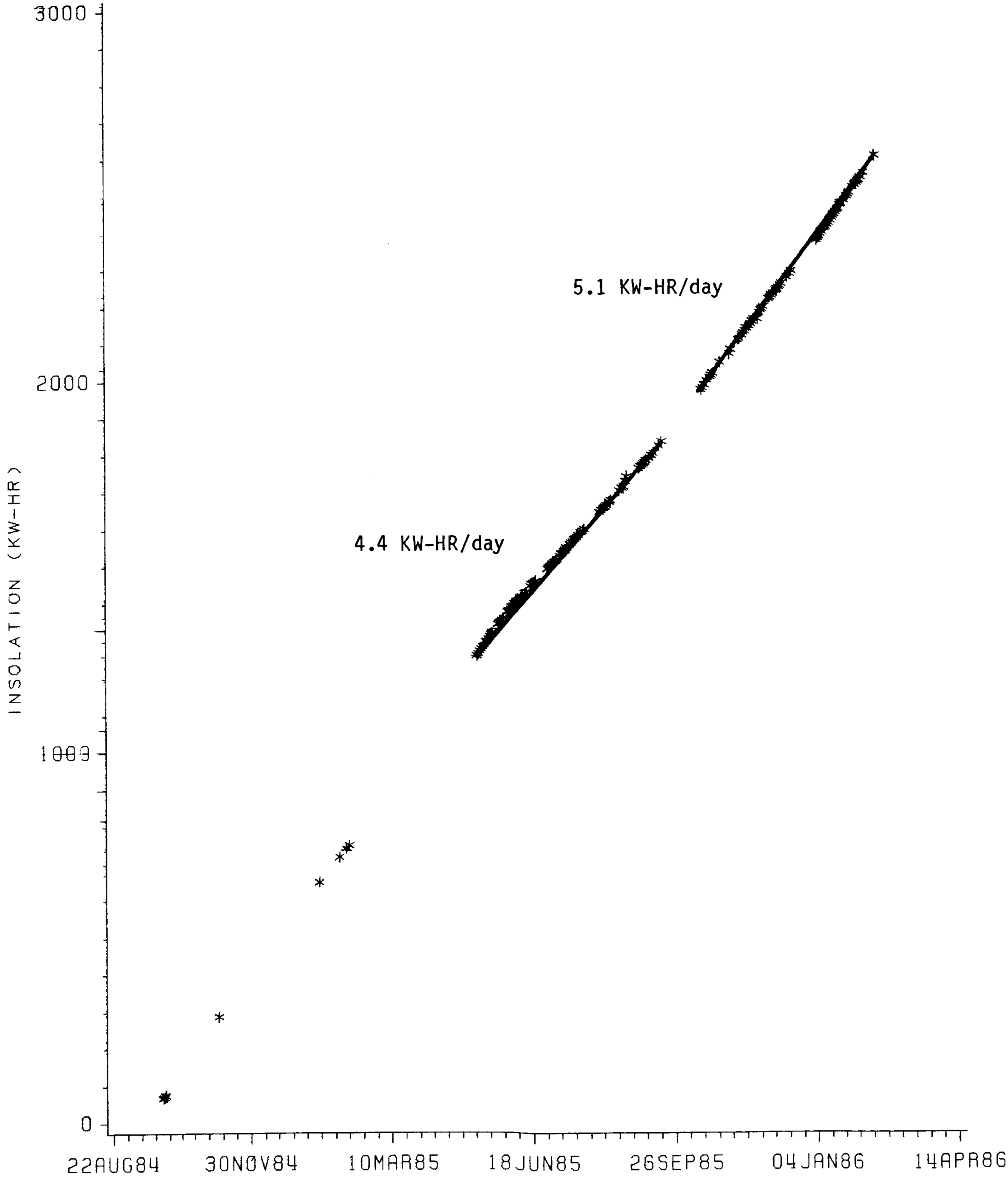


STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-33

DONGUILA

SCHOOL
INSOLATION



6.3.3 Nyali School

This system has not been installed, because of Education Ministry plans to construct a new school.

6.3.4 Onguia School

The Onguia school system operated without failure, and only required the replacing of two lamps (bulbs) during its first year of operation. Data collection for the system was poor, but allowed some analysis.

FAT and FIT data show a greater system performance than the yearly data. This can be attributed to the difference between daily readings, FAT, and FIT data, and the average readings for yearly data. The FAT data has a large discrepancy in the array ampere-hours and load ampere-hours (Figure 6-34) which can be interpreted as the initial system charging of the batteries.

Design objectives are greater than system performance data indicating that the system was not used to its full design potential. Array utilization factors range from a low of 15 percent in the yearly data to a high of 75 percent for the FAT data, with the 75 percent being greater than the design objectives. The insolation versus date graph (Figure 6-35) has a daily reading of six kilowatt-hours per square meter which is higher than the estimated values used for the design objectives (see paragraph 4.1.6.4).

Table 6-11 lists performance data parameters for the Onguia school system.

Table 6-11. Onguia School Performance Data

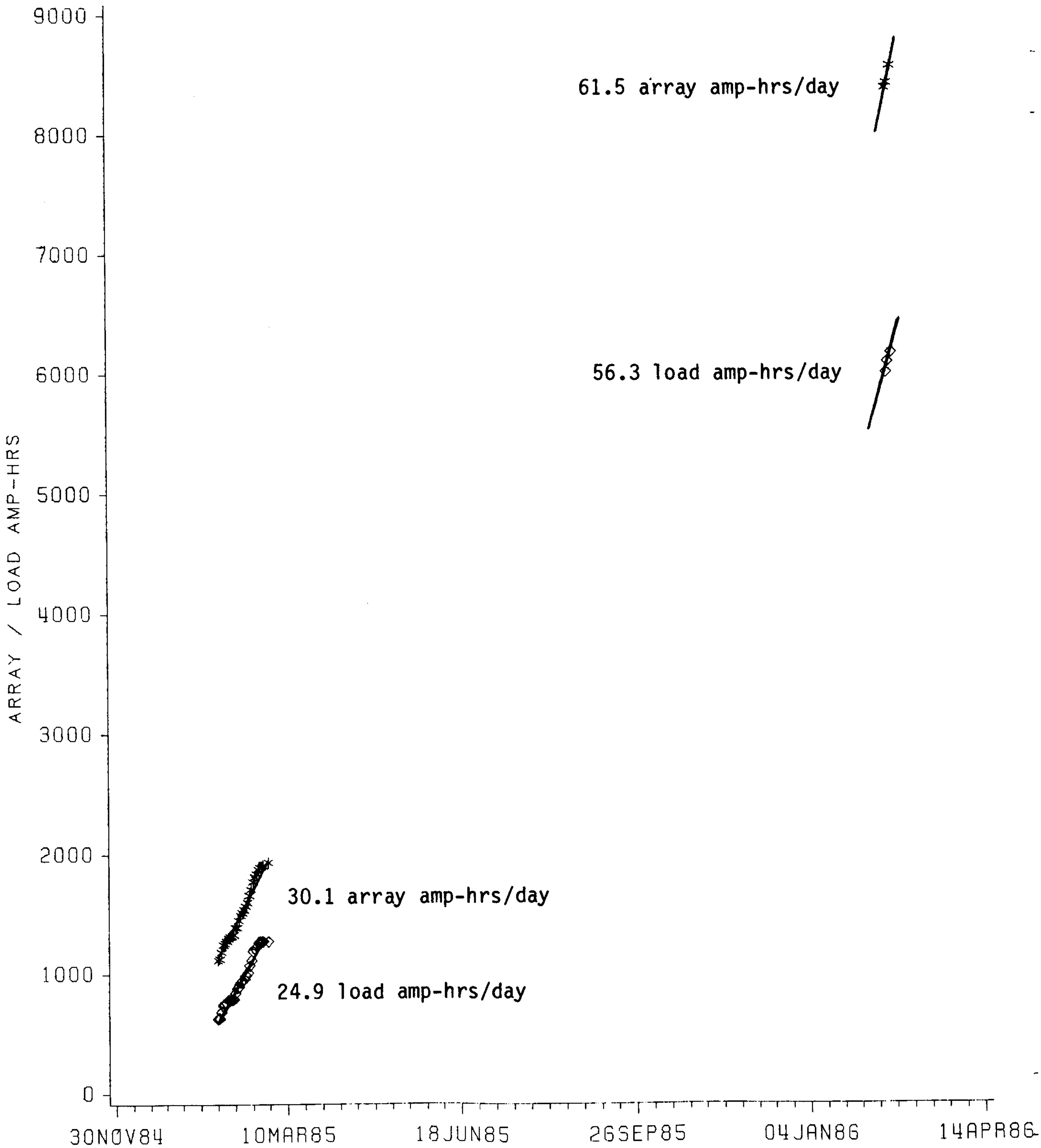
	Design Parameters	Final Acceptance Test Data (FAT) 1/27/85	Operational Data Low-High	Final Inspection Test Data (FIT) 2/22/86
Insolation ($kW-HR/M^2$)	4.16	3.3	4-6.1	4.2
Potential Array Output (amp-hours/day)	134	106	128-196	135
Array (amp-hours/day)	84	79.7	30.1-61.5	71.5
Array Utilization (percent)	63	75	15-48	53
Load (amp-hours/day)	84	88.1	24.9-56.3	38.5

FIGURE 6-34

ONGUIA

SCHOOL

ARRAY AND LOAD PERFORMANCE

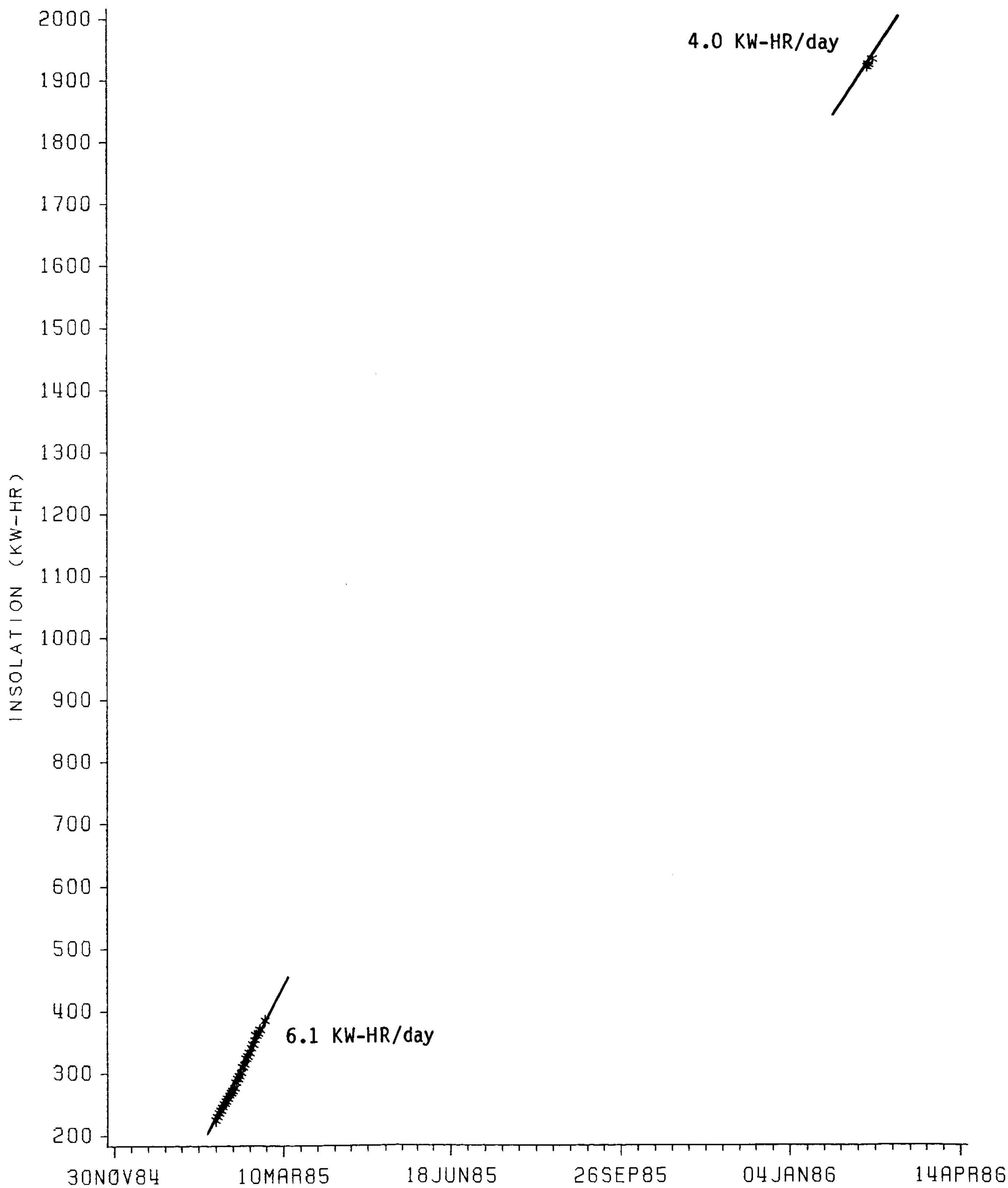


STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-35

ONGUIA

SCHOOL
INSOLATION



6.4 Village Lighting Systems

6.4.1 Bolossoville Light System

The Bolossoville light system operated without a system failure during the initial year of operation, except for the period from July 22 to December 13, 1985, when the system had a failed lamp (Figure 6-36). Data collection was sufficient for a system performance evaluation.

The 1.2 load ampere-hours per day during the period with the failed lamp is typical for the time/ballast circuit operating with a failed lamp and instrumentation power.

FAT, yearly, and FIT data correlated very closely, except during periods of lamp failure. Light operation time versus date graph (Figure 6-37) reveals that the run-time schedule of four hours per day was consistent throughout the year. During the FIT visit, the light run-time was changed to six hours per day.

Design objectives, when compared to performance data (Table 6-12), show that the system operated to its design potential, except when the lamp failed and was not replaced.

Table 6-12. Bolossoville Light System Performance Data

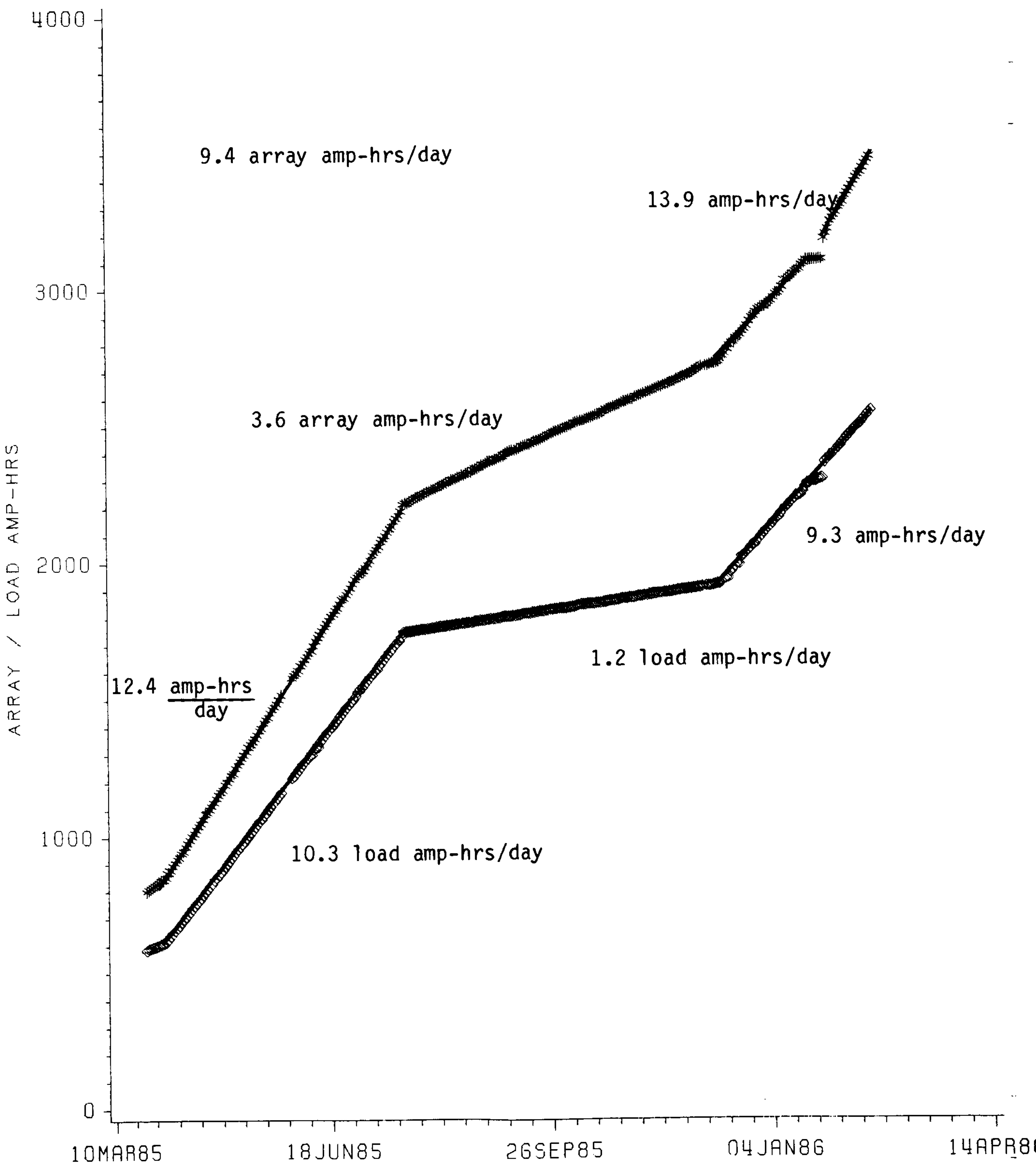
	Design Parameters	Final Acceptance Test Data (FAT) 2/03/85	Operational Data Low-High	Final Inspection Test Data (FIT) 2/19/86
Insolation ($kW-HR/M^2$)	4.16	4.1	3.5-4.4	IF
Potential Array Output (amp-hours/day)	19	19	16-20	NA
Array (amp-hours/day)	15	15.3	3.6-13.9	11.5
Array Utilization (percent)	79	80	23-70	NA
Load (amp-hours/day)	15	11.1	1.2-10.3	8.1
Run-time (hours)	4	5.1	4	3.9

IF=Instrument Failure
NA=Not Applicable

FIGURE 6-36

BOLOSSOVILLE

LIGHT SYSTEM
ARRAY AND LOAD PERFORMANCE

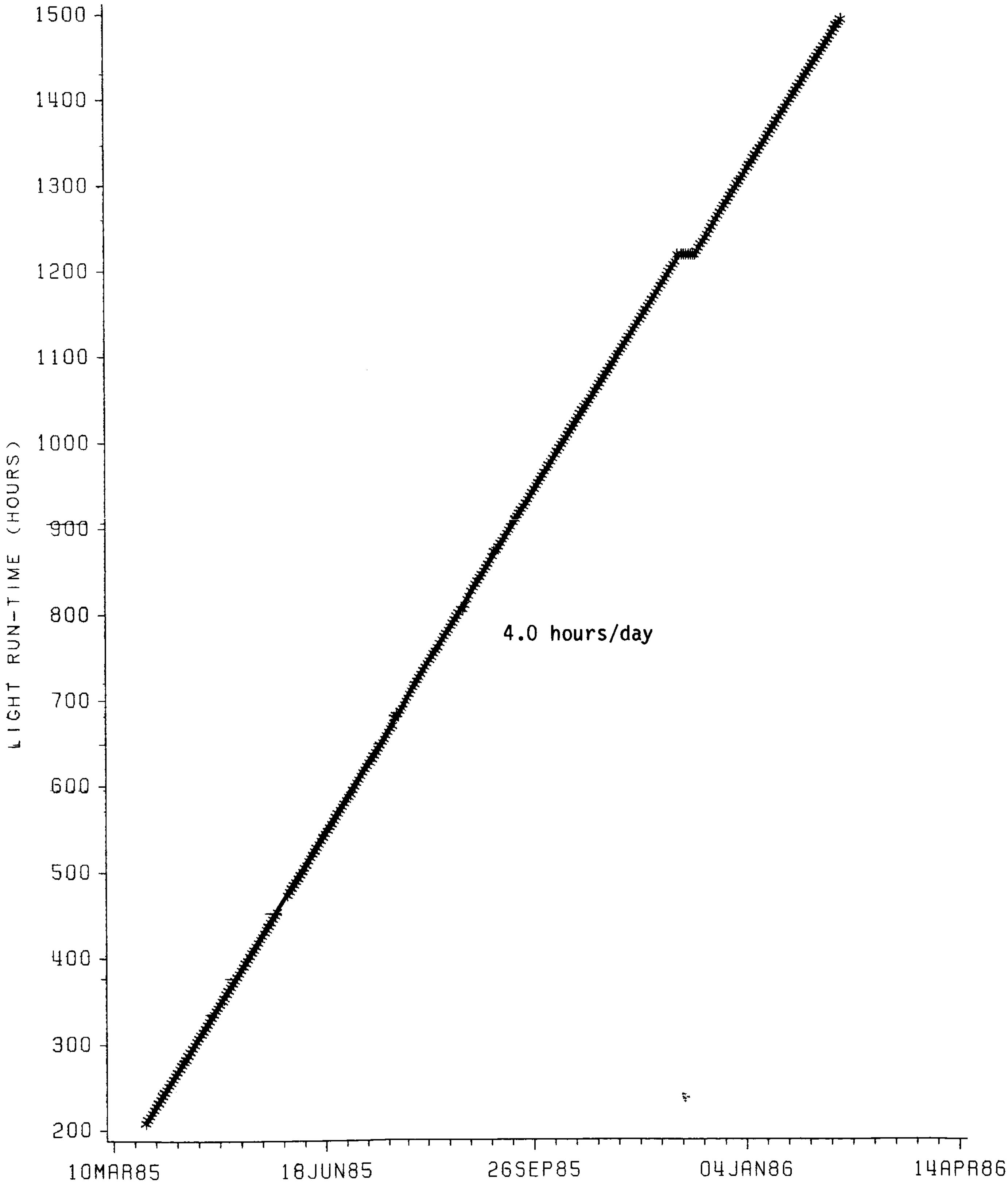


STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-37

BOLOSSOVILLE

LIGHT SYSTEM
LIGHT PERFØRMANCE



6.4.2 Donguila Light System

The Donguila village light system performed poorly during the operational period. Several verbal reports were received that the light was not operating the required number of hours and the alarm was often on. Several visits by the Ceca Gadis technician did not resolve the problem. A complete check-out during the Final Inspection Test visit in February 1986 determined that one of the batteries had developed a shorted cell. The shorted cell also affected the paralleled second battery. After replacement of the two batteries by spare batteries, the system operated properly and was reset for six hours per night operation.

Table 6-13 lists performance data for the Donguila light system. Figures 6-38 and 6-39 graph array/load performance and light run-time, respectively, for the system.

Table 6-13. Donguila Light System Performance Data

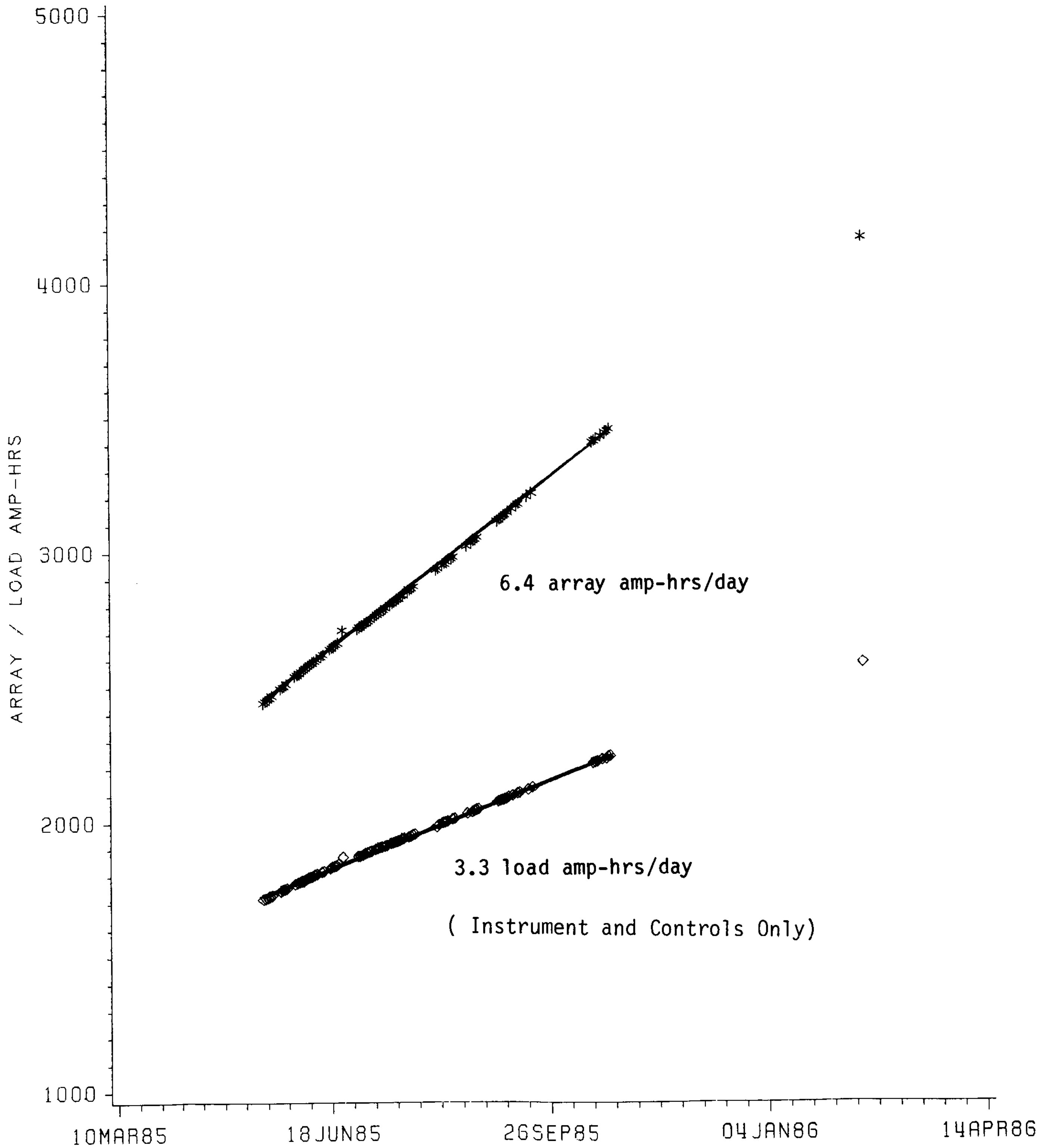
	Design Parameters	Final Acceptance Data (FAT) 1/18/85	Operational Data Low-High	Final Inspection Data (FIT) 2/17/86
Insolation ($kW-HR/M^2$)	4.16	4.78	4.4-5.1	5.73
Potential Array Output (amp-hours/day)	19	21.8	20-23.3	26.1
Array (amp-hours/day)	15	14.5	6.4	ID
Array Utilization (percent)	79	66	27.5-32	ID
Load (amp-hours/day)	15	10.9	3.3	15.6
Run-time (hours)	4	4	3.76	6*

*Changed to 6 hours

FIGURE 6-38

DONGUILA

LIGHT SYSTEM
ARRAY AND LOAD PERFORMANCE



STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

6.4.3 Nyali Light System

The Nyali light system operated without incident during the first year of operation and required only minimal maintenance during the FIT visit. Data collection throughout the year yielded a thorough evaluation of the system's performance.

There is no reported explanation for the data gap from 5 August 1985 to 20 September 1985, just a short note from the operator that he had returned on 20 September 1985. Apparently the light was shut-off for most of this period, or the lamp bulb had failed. The voltage was recorded only as integers by this operator, but did not indicate any problems.

Operational and FIT data compared closely with run-times being four hours per day, and total load consumption at an average of 10.5 ampere-hours per day. The FAT data has a load consumption greater than the array production, indicating a draw on the system batteries. However, opeation during the year indicated sufficient array capacity to extend light run-time to six hours per day. Therefore, during the FIT visit, the light run-time was reset to six hours per day.

Table 6-14 shows performance data parameters for the Nyali light system. Figures 6-41 and 6-42 graph array/load performance and light run-time, respectively, for the Nyali light system.

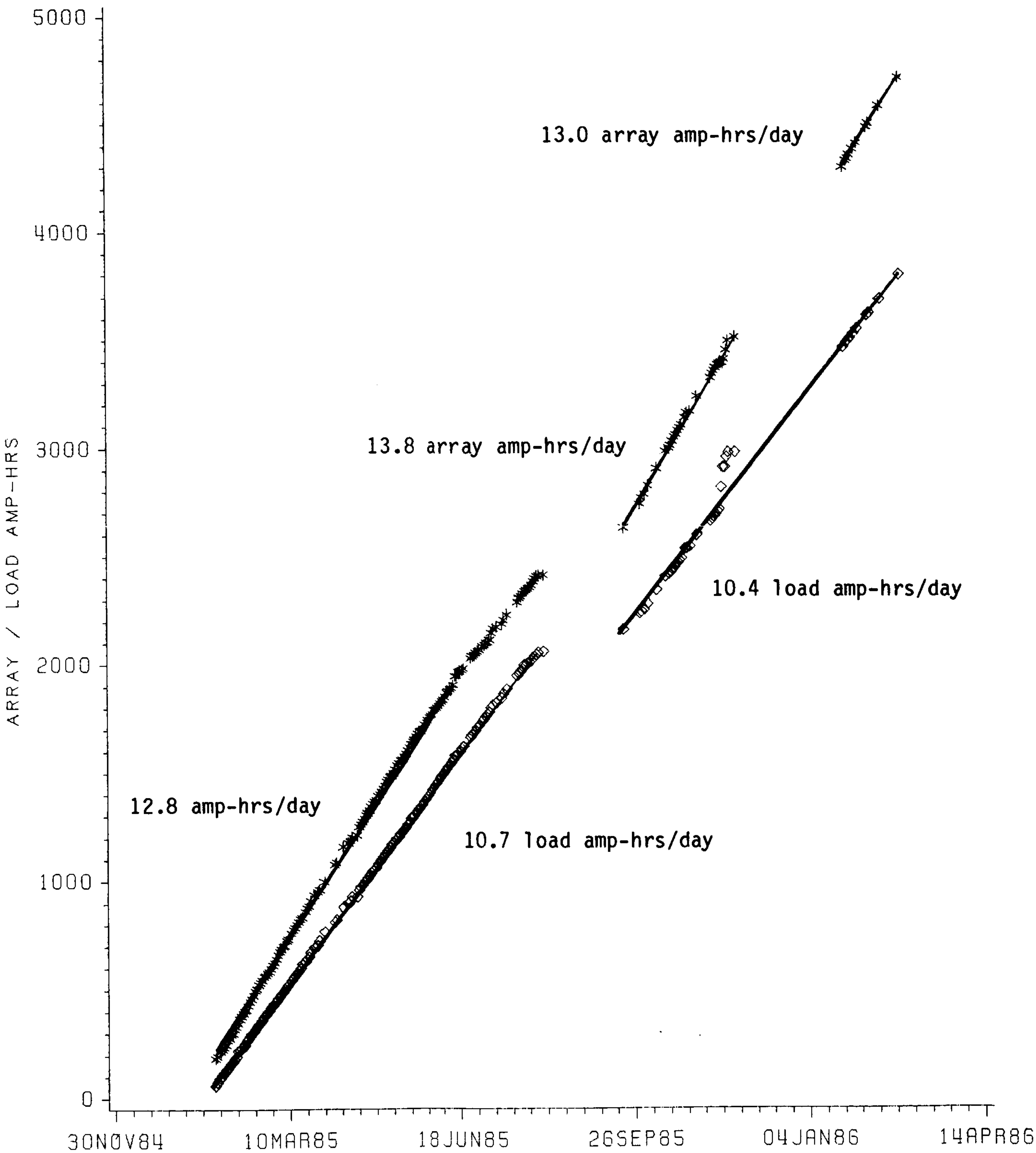
Table 6-14. Nyali Light System Performance Data

	Design Parameters	Final Acceptance Data (FAT) 1/23/85	Operational Data Low-High	Final Inspection Data (FIT) 2/25/86
Insolation ($kW\text{-}HR/M^2$)	4.16	3.34	4.68	2.1
Potential Array Output (amp-hours/day)	19	15	22	10
Array (amp-hours/day)	15	7.6	13.2	12.1
Array Utilization (percent)	79	48	60	121
Load (amp-hours/day)	15	15.9	10.6	10.4
Run-time (hours)	4	6	4	3.9

FIGURE 6-40

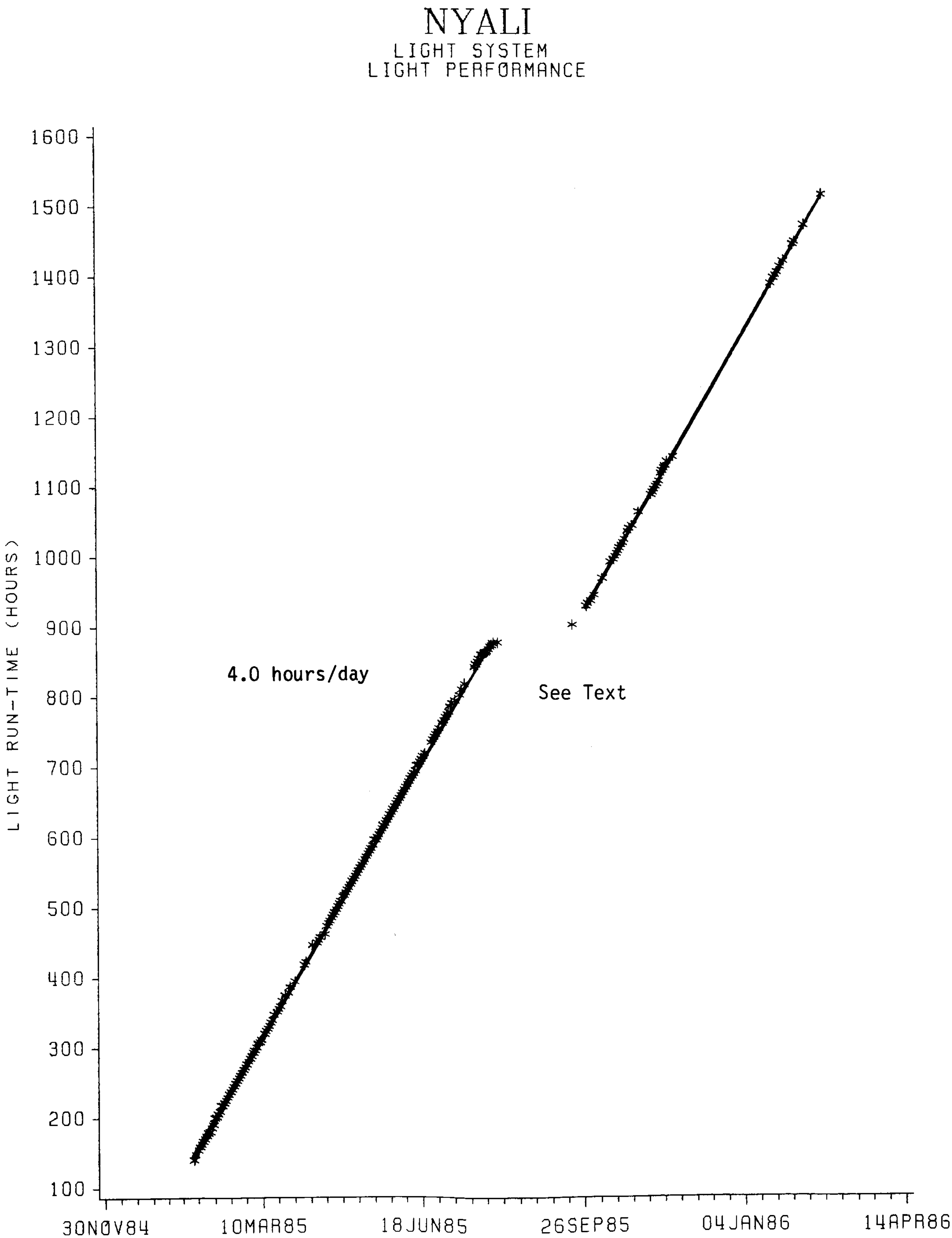
NYALI

LIGHT SYSTEM
ARRAY AND LOAD PERFORMANCE



STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-41


NYALI
LIGHT SYSTEM
LIGHT PERFORMANCE
LIGHT RUN-TIME (HOURS)
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
4.0 hours/day
See Text
30NOV84
10MAR85
18JUN85
26SEP85
04JAN86
14APR86

6.4.4 Onguia Light System

Data collection for the Onguia light system was intermittent throughout the year which led to an insufficient evaluation of the system's performance. The battery subsystem was plagued with loose connections on the jumper cables, on the battery connections, and on all circuit breakers. These, along with incorrect wiring of a battery charger regulator, compromised the system performance and led to the failure of the one connected battery. The problems with the system were corrected, and the system was left in operation with one battery at the completion of the FIT visit.

The array monitor with the ampere-hour meter failed in shipping and was removed for repair during the FAT visit. It was not replaced for several months and was the primary cause of insufficient data on the system's operation. Design objectives correlated poorly with operational data which resulted from sparse data collection.

This village light was left operating four hours per night because of heavy dirt accumulation on the array and there being only one battery available.

Table 6-15 shows performance data parameters for the Onguila light system. Figures 6-42 and 6-43 graph array/load performance and light run-time, respectively.

Table 6-15. Onguia Light System Performance Data

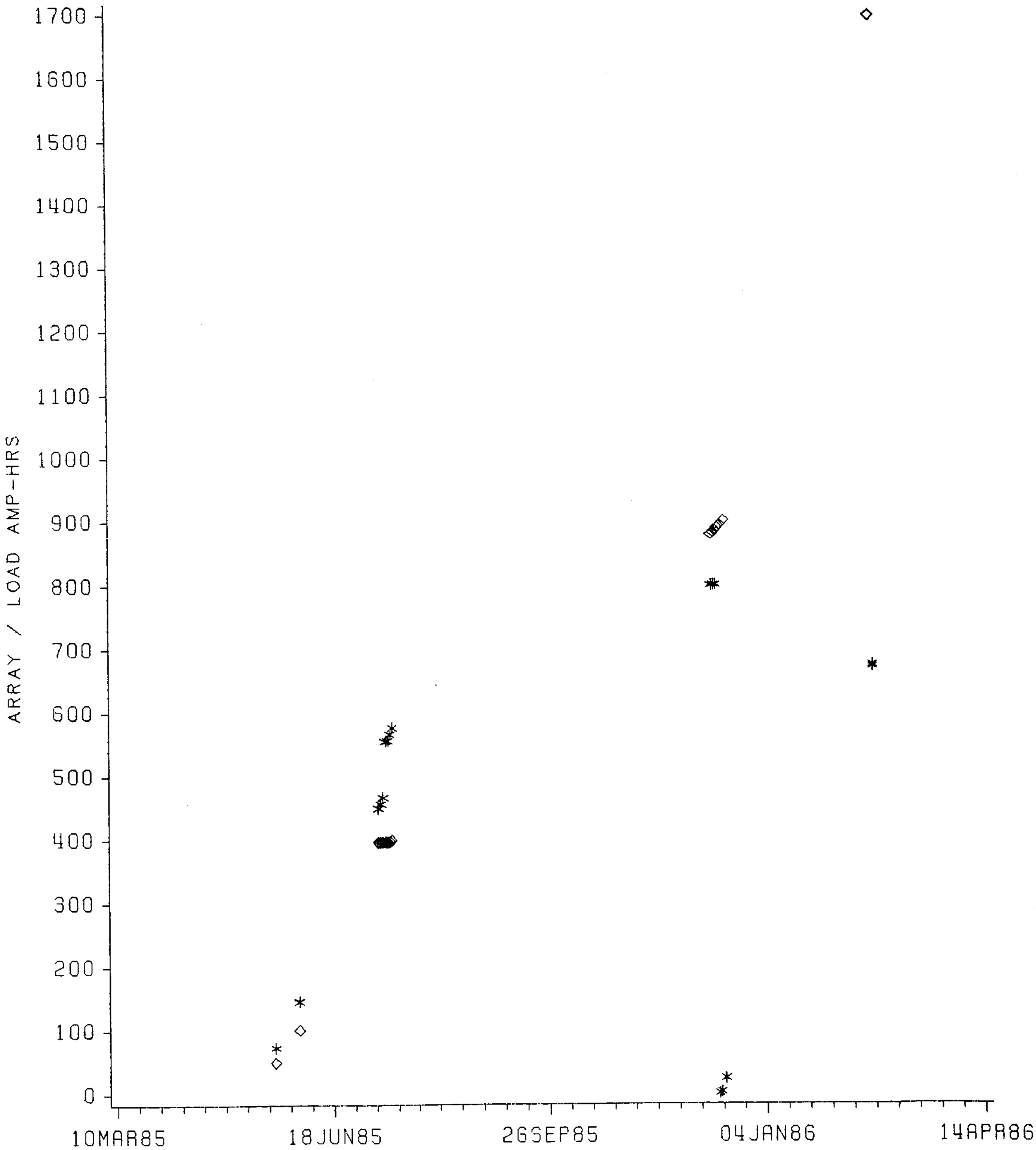
	Design Parameters	Final Acceptance Data (FAT) 1/27/85	Operational Data Low-High	Final Inspection Data (FIT) 2/22/86
Insolation ($kW-HR/M^2$)	4.16	3.3	4-6.1	4.2
Potential Array Output (amp-hours/day)	19	15	18-28	19
Array (amp-hours/day)	15	IF	7.3-21.2	12.1
Array Utilization (percent)	79	N.A.	40-76	64
Load (amp-hours/day)	15	IF	5.1-11.7	10.4
Run-time (hours)	4	4	1.2-3.8	4

IF=Instrument Failure

FIGURE 6-42

ONGUIA

LIGHT SYSTEM
ARRAY AND LOAD PERFORMANCE

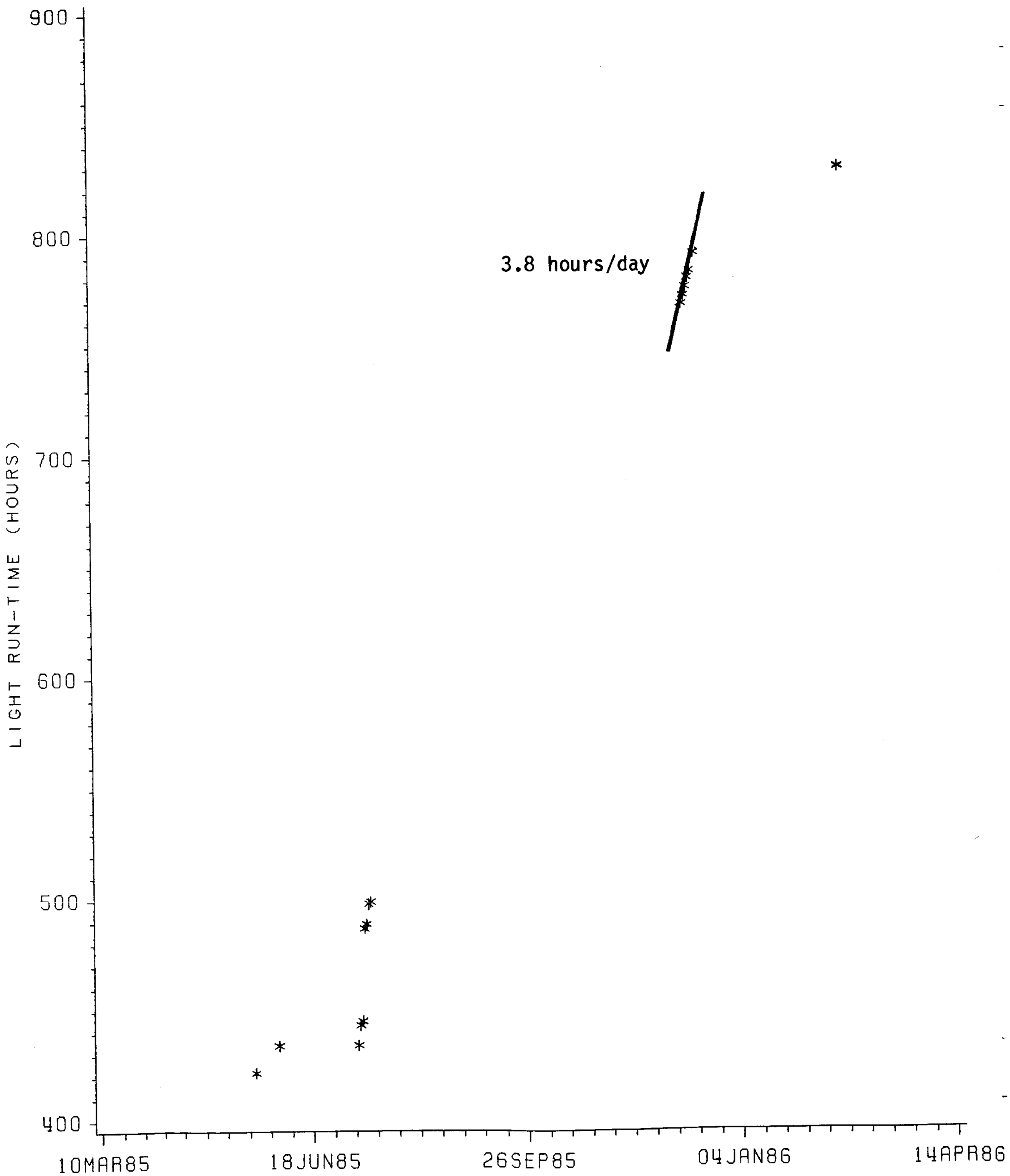


STAR: ARRAY AMPERE-HOURS
DIAMOND: LOAD AMPERE-HOURS

FIGURE 6-43

ONGUIA

LIGHT SYSTEM
LIGHT PERFORMANCE



6.5 Bolossoville Community Center

During its first year of operation, the Bolossoville community center required the replacement of a battery charge regulator and adjustment of the VCR power input. Several of the fluorescent light ballasts failed during the year and were replaced. These replacements were not noted in the equipment log book. Data collected throughout the year gave a good description of the system's performance.

FAT and FIT data have greater total system ampere-hour consumption than the yearly data. There are numerous occasions when the daily data, FAT, and FIT, are greater than the design objectives as can be seen in the array ampere-hour versus day graph (Figure 6-44). This represents different system usage patterns of the villages; apparently the building is not in constant use by the villagers. The failed fluorescent light ballasts could also have caused low power consumption (Figure 6-45).

Comparing design parameters to performance data (Table 6-16) shows that the system was not utilized to the extent assumed for in the system design. This is also evident from the array utilization data.

Table 6-16. Bolossoville Community Center Performance Data

	Design Parameters	Final Acceptance Data (FAT) 2/04/85	Yearly Data Low-High	Final Inspection Data (FIT) 2/18/86
Insolation ($kW\text{-}HR/M^2$)	4.16	4.1	3.5-4.4	IF
Potential Array Output (amp-hours/day)	134	132	113-142	N.A.
Array (amp-hours/day)	74	35.4	5.6-11.3	29.5
Array Utilization (percent)	55	27	5-8	N.A.
Load (amp-hours/day)	74	13.4	2.1-7.8	24

IF=Instrument Failure

FIGURE 6-44

BOLOSSOVILLE

COMMUNITY CENTER
ARRAY PERFORMANCE

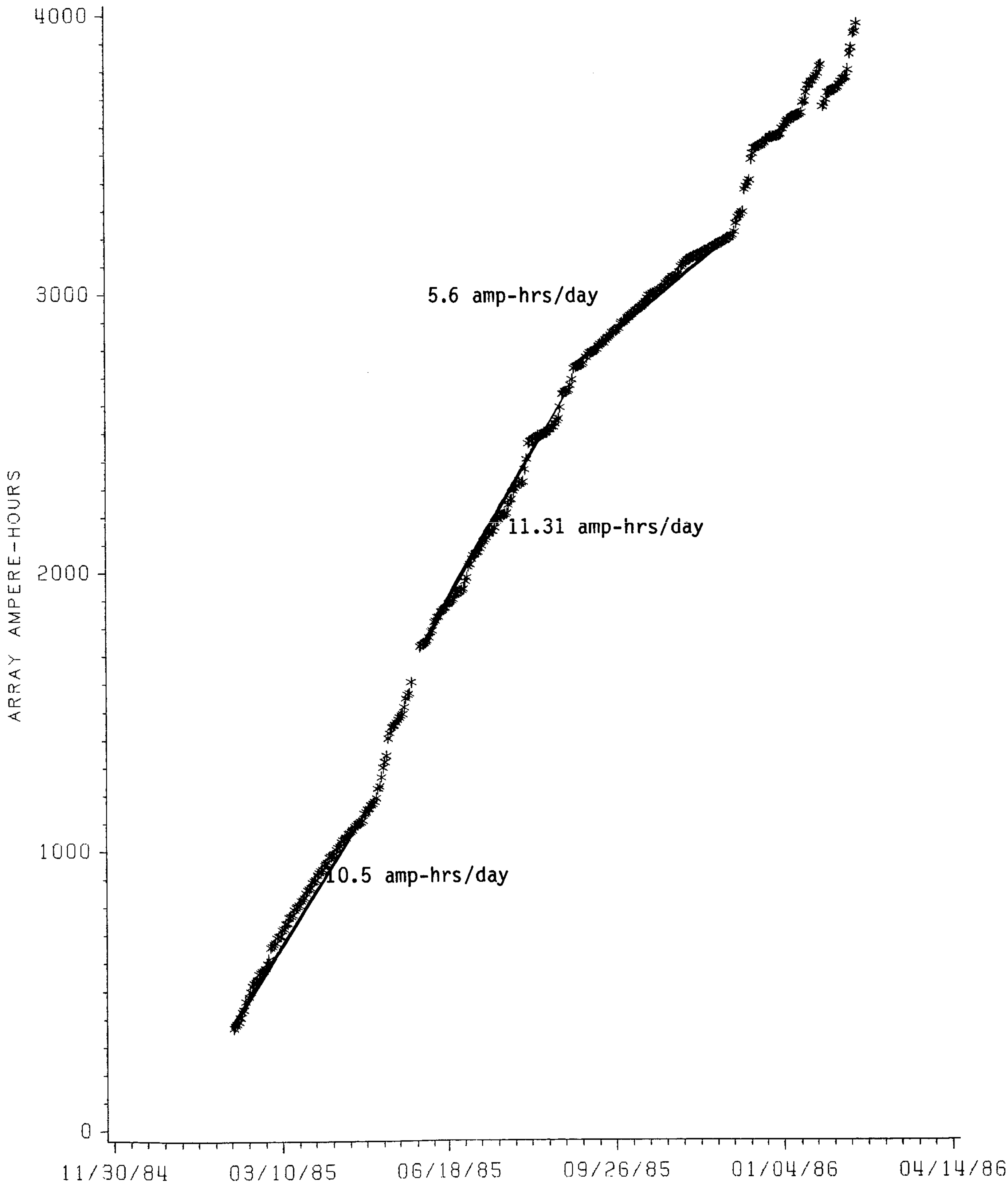
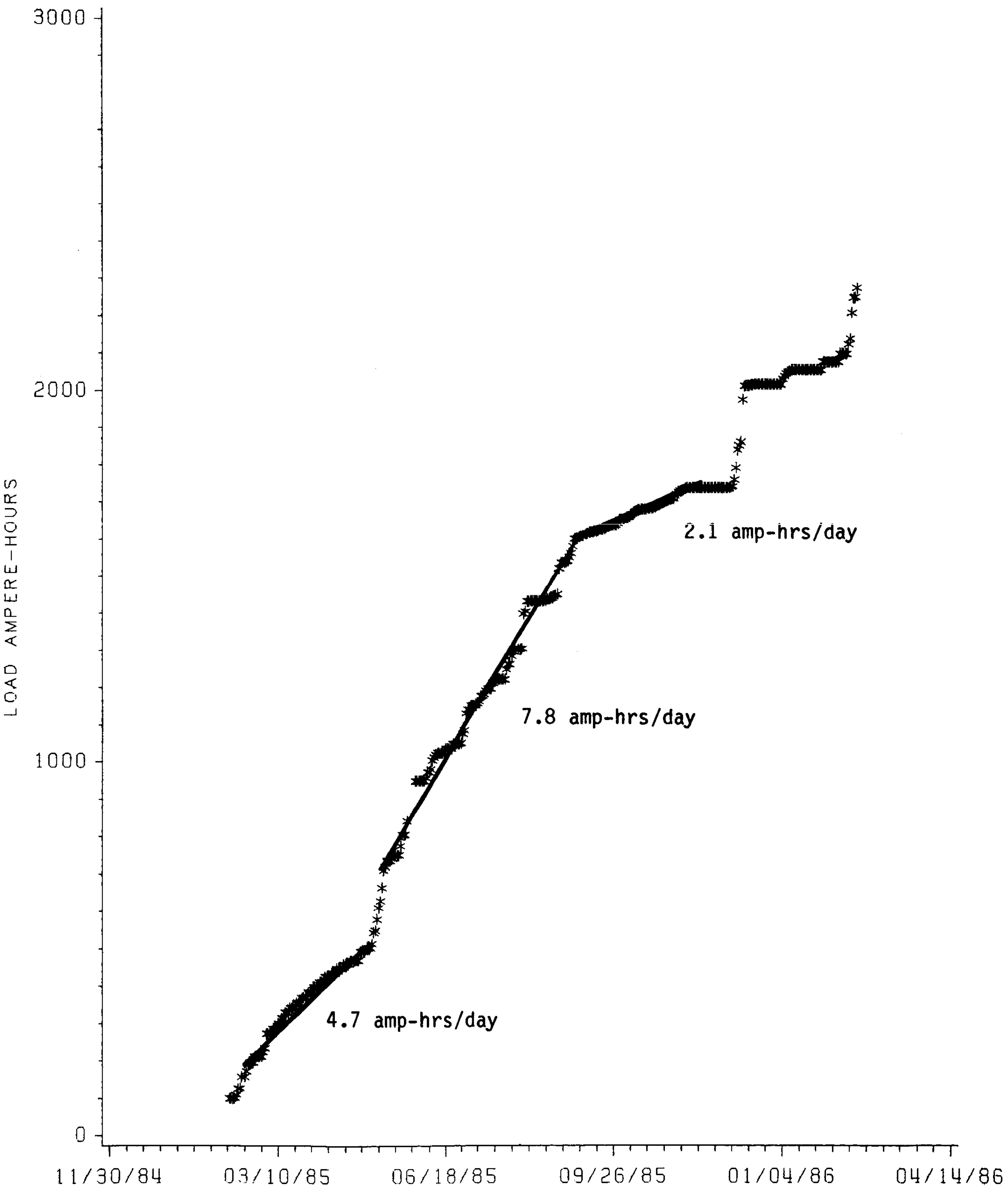


FIGURE 6-45

BOLOSSOVILLE

COMMUNITY CENTER
LOAD PERFORMANCE



UNITS = KW-Hr/d

6.6 Monthly Insolation Summary

Month/Year	Bolossoville Average		Donguila Average		Nyali Average		Onguia Average	
	Days of Data	Insolation Units	Days of Data	Insolation Units	Days of Data	Insolation Units	Days of Data	Insolation Units
JAN/85	NO	DATA	NO	DATA	5	3.69	2	5.77
FEB/85	3	5.60	7	4.5	28	4.94	27	5.49
MAR/85	31	4.94	NO	DATA	30	5.64	NO	DATA
APR/85	30	5.03	NO	DATA	12	3.37	NO	DATA
MAY/85	31	4.63	19	5.30	28	4.47	NO	DATA
JUN/85	30	4.17	29	4.07	26	4.51	NO	DATA
JUL/85	31	3.56	25	4.19	30	4.32	NO	DATA
AUG/85	31	4.22	19	5.02	8	4.51	NO	DATA
SEP/85	NO	DATA	16	4.52	3	4.12	NO	DATA
OCT/85	NO	DATA	13	5.71	21	4.63	NO	DATA
NOV/85	NO	DATA	24	5.28	NO	DATA	NO	DATA
DEC/85	25	3.23	16	4.69	NO	DATA	NO	DATA
JAN/86	28	3.70	24	5.33	9	4.59	NO	DATA
FEB/86	NO	DATA	16	5.2	24	4.52	2	6.02

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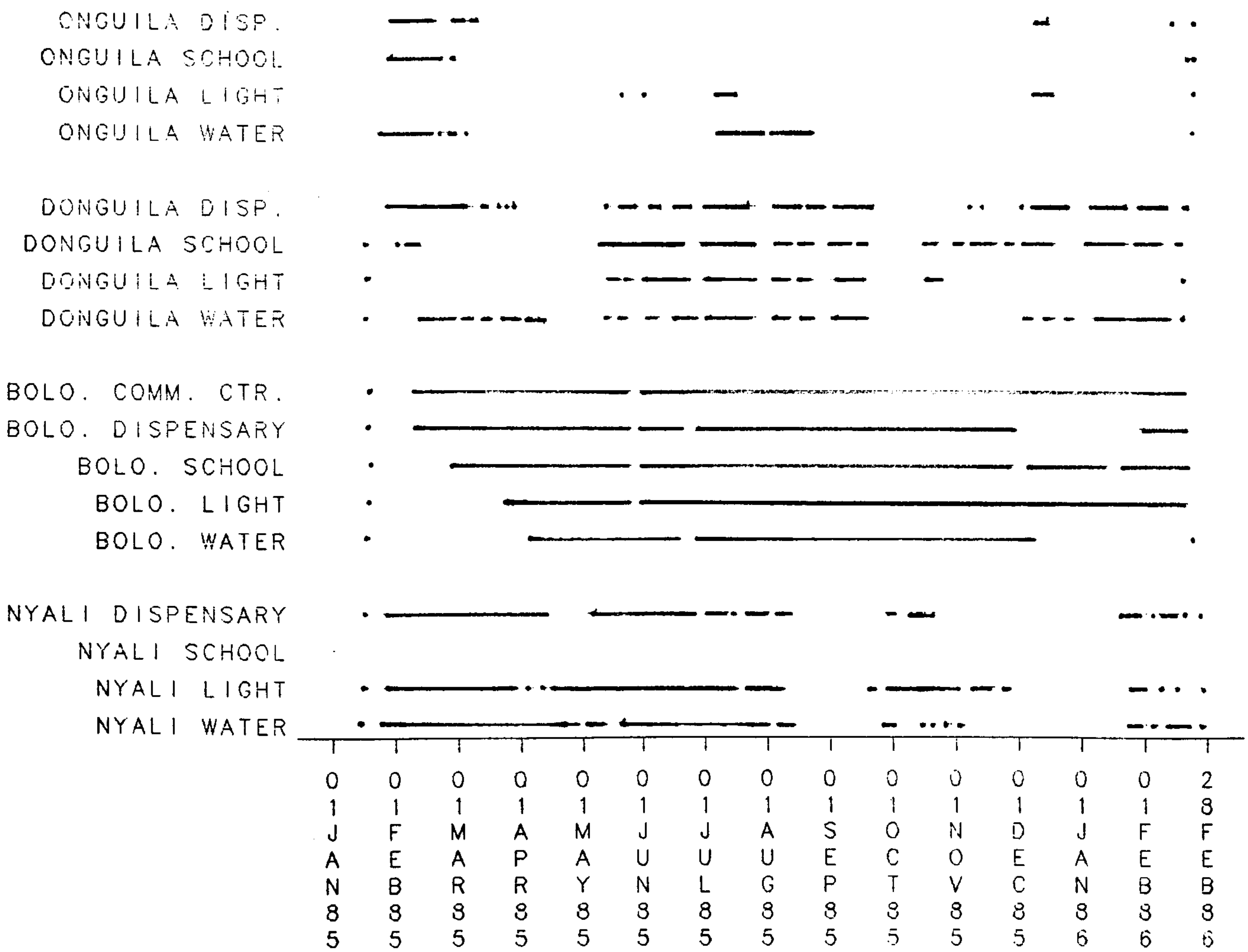
OF POOR QUALITY

DAILY DATA RECEIVED BY SOLAVOLT



DATA RECEIVED THROUGH MAY 6, 1986

Section 7. MANUALS

Solavolt supplied User/Operator and Maintenance/Repair manuals for each type of system. There are a total of nine different manuals each in English and French. Each of the five types of systems has its own User/Operator manual but it was decided that a separate Maintenance/ Repair manual for the Bolossoville community center was not necessary as the school system Maintenance/Repair manual contained the same information.

7.1 User/Operator Manuals

The User/Operator manuals were produced in a 8 1/2 inch by 11 inch format with two sided printing and plastic binding. Simple graphics were used on the cover to illustrate the system components and required data collection. The layout of instrument panels, data recording sheets and the manual were coordinated with the actual instrument panels for ease of data collection. The User/Operator manual uses a system of large circled numbers on a picture of the instrument panel to identify where to read each of the required parameters. The same numbers are repeated on the data forms and the actual instrument panels.

A binding machine was provided to MERH to facilitate changes or additions to the user manuals in Gabon.

Production of the manuals was accomplished by a group of professional manual writers in the Government Electronics Group of Motorola, Inc. Motorola is one of the parent companies of Solavolt.

During the preparation of both the manuals and training materials, Solavolt received invaluable assistance from Dr. Allen Roberts of the University of Michigan and Mr. Anthony Ratajczak of NASA/LeRC. Dr. Roberts and Mr. Ratajczak provided both careful review and valuable contributions over the several iterations between preliminary outline and final text stages of the documentation.

As an example of the content of the manuals, Appendix D contains the index to the dispensary User/Operator manual.

7.2 Maintenance/Repair Manuals

The Maintenance/Repair manuals were produced in an 11 by 17 inch single sided format. This approach was used because of the inclusion of many large drawings and the prior experience that often folded paper easily tears in a tropic environment.

The Maintenance/Repair manuals repeat some of the text of the User/Operator manuals pertaining to how the system operates. Substantial effort was spent on developing and explaining easy to follow troubleshooting trees. For each type of system, the Maintenance/Repair manuals contain representative site plans, wiring diagrams, schematics and other drawings that may be required for proper maintenance and repair. These manuals also contain lists of all spare parts, tools, replacement parts and supplies that may be required for the system. Manufacturers data on all equipment is included in these manuals. For some of the equipment, a French language version of the manufacturers' data was available and was included in the French version of the manual. Appendix E contains the index of the dispensary Maintenance/Repair manual and an example of the troubleshooting charts.

Section 8. TRAINING

Solavolt prepared, in accordance with approved outlines, training programs and materials necessary to train in-country personnel in the use, operation, maintenance, troubleshooting, and repair of each type of system. These training materials and training programs were to incorporate the user manuals, appropriate visual aids and/or models, and were prepared for presentation in both English and French.

The training program was designed to prepare the users to assume complete responsibility for continued successful and safe operation of the Systems.

The major elements of the training program as developed are teacher's guides to each of the manuals and a training aid/demonstrator system to be used in training. All training material had been translated into French.

The training materials were developed with the help of Dr. Allen Roberts, an anthropologist, who has visited the villages and studied the people. There are three major groups that required training:

Installers
Users
Maintenance/Repair Personnel.

Solavolt used on-the-job training and French language drawings to train the installers during the installation of the systems in Donguila. Ceca Gadis, the subcontractor to Solavolt for installation, had the responsibility for training the users and maintenance/repair personnel using the materials supplied. MERH had the responsibility of identifying and providing for training the personnel who would operate and maintain/repair each system and for scheduling the training.

The training aid consists of a table-top photovoltaic system which contains a 10-watt module, a small battery, a voltage regulator, an ammeter, a voltmeter and the necessary connections. The training material also includes large-size reproductions of the data sheets for classroom use and a large simulated panel meter for teaching system operators how to read analog instruments.

No formal training sessions were held due to administrative problems and schedule conflicts. The training materials have been turned over to S.E.E.G. for training center. As of the date of this report plans were being made by MERH and S.E.E.G. to install the system originally intended for the Nijali school at the S.E.E.G. training center and use it for instructional purposes.

9.0 PERFORMANCE SUMMARY AND RECOMMENDATIONS:

9.1 Systems Performance Summaries

9.1.1 PERCENT PHOTOVOLTAIC POWER SYSTEM AVAILABILITY

VILLAGE	PUMP SYSTEM	DISPENSARY SYSTEM	SCHOOL SYSTEM	VILLAGE LIGHT SYS.	COMMUNITY CENTER SYS.
DONGUILA	100	100	100	(1) 20 to 50	N/A
NYALI	100	100	Not Installed	100	N/A
ONGUIA	100	100	100	(2) 50 to 60	N/A
BOLOSSOVILLE	100	100	100	100	100

N/A = Not Applicable

(1) Battery problem, instrument failure.
(2) Based on total number of runtime hours during first year. Performance limited by battery failure.

9.1.2 MAJOR PROBLEM AREAS

VILLAGE	PUMP SYSTEM	DISPENSARY SYSTEM	SCHOOL SYSTEM	VILLAGE LIGHT SYSTEM	CENTER SYS
DONGUILA	Excessive Water Consumption	40 Watt fluorecent lamps Refrigerator wiring Voltage Regulator	40 Watt fluorecent lamps TV voltage regulator	Battery Darkness Sensor	N/A
NYALI	Water Meter	40 Watt fluorecent lamps Refrigerator wiring Voltage Regulator	Not Installed		N/A
ONGUIA	Pump Motor	40 Watt fluorecent lamps Voltage Regulator Refrigerator ECM	40 Watt fluorecent lamps	Battery Connector Array Monitor Darkness Sensor	N/A
BOLOSSOVILLE	Pump Motor	40 Watt fluorecent lamps Voltage Regulator Refrigerator ECM	40 Watt fluorecent lamps Voltage Regulator	Lamps	40 Watt fluorecent lamps TV

9.2 Recommendations

9.2.1 Design:

9.2.1.1 Array structure:

The present structure proved to be satisfactory in that it provides for an integrated power system installation. A package design that does not require a flat concrete pad would be more desirable. All the wiring for the modules should be precut as a minimum, and possibly have the panels for the array factory assembled.

9.2.1.2 Pumping Systems:

The annual insolation profile in Gabon and the ground water supply in two of the villages presented a design problem for batterless pump systems. First, there are two extended dry seasons in Gabon that are characterized by almost total overcast and two Wet seasons that are characterized by periods ranging from overcast to full sun. Secondly, the well in Bolossoville had a very low yield. This necessitated a PV system design which would allow the pump to lift the maximum amount of water for the maximum amount of time each day in order to provide the required amount of water for the villagers.

A PV system designed to produce adequate water during the consecutive overcast days of the dry season provides too much power under clear sky conditions, and very high power during short periods with bright clouds. Such array high outputs can damage some pump motors used with batteryless pump systems. Such was the case in Gabon. The only practical solution to this situation is to install a simple and reliable current limiting device in the array control subsystem. Such device can most easily take the form of an array output controlled switch or switches that disconnect and reconnect portions of the PV array consistant with the maximum power rating of the pump motor.

9.2.1.3 Instrumentation:

These systems were instrumented to record data which would allow extensive system performance analysis. Clearly that much instrumentation is not necessary in a normal setting. Experience has shown, however, that minimum instrumention is desirable to allow the local operator to observe and monitor system operation. That minimum system instrumentation is a system voltmeter and separate array and load ammeters.

Analyses indicated a need for additional pump system instrumentation which would record the potential pump operation time; i.e.; instruments which could measure directly or allow one to calculate the amount of water that could have been pumped if the water tank had not been full and the pump shut off. If a water pump does not perform properly, it is very difficult to determine the cause without knowledge of how much of the potential pumping time the pump is actually pumping water. Also a means of measuring the actual depth to water, such as a plastic tube inserted into the well during pump installation, should be provided. This is a valuable (and inexpensive) diagnostic aid.

One of the refrigerators suffered performance problems when wires to the remote mounted runtime meter were short-circuited by rats eating the wire insulation. The design of instrumentation should therefore assure that failure of instrumentation (or wiring to the instrumentation) cannot affect load operation.

9.2.2 Component Selection

9.2.2.1 Electrical load devices:

There were many problems with the fluorescent and low pressure sodium lights and with being able to supply replacement lamps. The original DC fluorescent light fixtures had a high failure rate and short lamp life. The outdoor lights use 18-watt Low Pressure Sodium (LPS) lamps that are difficult to obtain. Any project in remote areas should utilize either lighting equipment for which replacement assemblies and components are locally available, or tested special equipment with known long life. With either selection, adequate spares must be supplied with the initial installation. Use of AC distribution systems and load devices should be considered, but the reliability and serviceablility of the inverter must be established. It is a single point failure device which can disable all loads.

9.2.2.2 Fans:

These devices (ceiling casablanca type fans) did not provide much if any cooling effect. Buildings in most remote locations in the tropics and other hot environments (outside the U.S.) are designed to take advantage of natural cooling and do not appear to benefit substantially from these devices.

9.2.2.3 Water Systems:

Both High Density Polyethylene (HDPE) and galvanized pipe were used in the water distribution systems. HDPE pipe is clearly superior to galvanized pipe and is available in most countries.

The self-closing water faucets commonly available in the U.S. are superior to the European push-button type self-closing faucets available in Africa. However, the local plumbers must be shown how and when to adjust the tightness of the knobs. The design of the U.S. type faucets is such that leaks can occur if the knob becomes too loose because the selfclosing spring also provides the tension on the knob detents.

9.2.2.4 Televisions and Video Cassette Recorders/Players:

Different countries use different TV broadcast standards. Since U.S. law prohibits the import of electronic equipment that does not meet U.S. interference standards, TV's and VCR's compatible with foreign broadcast standards - which would not be tested for interference since they could not be used in the U.S. anyway - are not available in the U.S. for use during system design and test. The system designer, therefore, must purchase the equipment early in the design process either in the country of use or in a supplying country, have a local technician measure the power requirements, check TV/VCR compatibility, and arrange for a supply of repair parts and documentation (manuals and schematics).

9.2.2.5 Miscellaneous:

Keyed alike padlocks were used to secure all equipment. However, the padlocks themselves were not secured by short chains and so some were lost or were used for other purposes. Even though the locks were designed for outdoor service, rain made some difficult to operate. The locks, therefore should be provided with and lubricated with a non-water soluble lubricant.

Clipboards were provided for recording data. Based on other experiences, this seemed to increase the amount of data being recorded, improved legibility, and reduced errors.

The Marvel vaccine refrigerators (the type used in this project) come equipped with a pull-down/maintenance switch. Deliberate or inadvertant operation in the pull-down mode increases power consumption. Based on experience here and from other projects, the pull-down mode is unnecessary and the switch should be eliminated. Marvel has eliminated this switch on present production models.

9.2.3 Equipment Packaging and Shipping

9.2.3.1 Equipment Packaging:

Where multiple systems are being installed in a single location and/or single or multiple systems are being installed in multiple locations, the equipment for each system should be packaged separately. Such was not always the case with the equipment shipped for this project. As a result there were some field problems due to transportation, changes in installation plans, environmental damage, and errors during installation. Also, there were some losses due to negligence and/or pilferege after packages were opened.

9.2.3.2 Package Size:

Material handling equipment is not available in many areas. Therefore, equipment should be packaged so that the packages can be handled by no more than four men. This avoids damage to the equipment and loss of equipment from packages that have to be opened to reduce weight and/or size to allow for manual handling in transit or at the installation site. The extra cost of crating large batteries in smaller packages may prove an exception. However, if automotive size batteries are used, they should be packed (boxed) not more than two to a box. In the case of this project, many boxes were so large that they could only be moved by materials handling equipment and this caused problems and delays when transfering the equipment from the overseas shipping containers to temporary storage and then to trucks for in-country delivery.

9.2.3.3 Refrigerators:

Temperature recorders attached to the outside of refrigerators must be securely fastened to the refrigerator. Further, the refrigerator shipping box must have specific provisions for supporting the recorder. Some damage to refrigerators and recorders occured during shipment by truck in-country over the rough roads. The shipping box should be retained in tact with the refrigerator in case there is a need to move the equipment some distance for repair.

9.2.3.4 Marking:

All boxes and crates must be permanently marked to indicate the contents and destination. Shipments may be subjected to rain during shipping and delays prior to installation. Markings that become illegible can cause serious problems. Multiple copies of complete and detailed documentation cross referencing box numbers, contents and system application must be available in the field. Such practice was followed in this project and proved invaluable during installation.

9.2.3.5 Other:

Edible looking packing materials such as foam "peanuts" should not be used in boxes that will be unpacked in remote areas. These foam "peanuts" are attractive looking foreign items that were eaten by unsuspecting children and animals. They are also very difficult to contain and end up littering the area.

Shipping containers should be loaded with due consideration for removing the contents in humid locations. In this project the wooden boxes, packed tightly in overseas shipping containers in Phoenix, Arizona, swelled inside the steel containers and were very difficult to remove in humid Gabon. Also the container should be loaded so as to minimize the unloading effort, assuming that materials handling equipment will not be available to unload the containers; e.g. heaviest boxes on bottom and closest to the door.

10.0 SUMMARY

Sixteen community service photovoltaic powered load systems were installed in four villages in Gabon between September 1984 and February 1985. These systems include: 1) a potable water pumping and water distribution system in each village, 2) a dispensary system in each village and having a vaccine refrigerator, dispensary interior and exterior lights and a ceiling fan, 3) school systems in three villages and having classroom lights, a television set and a video cassette recorder/player, and a school system in the fourth village (Bolossoville) having only classroom lights, 4) a single outdoor street light in each village, and 5) a community service system in Bolossoville having lights and a television and a video cassette recorder/player. All of the systems were extensively instrumented to provide data for systems performance analysis.

Performance data and related experience indicates that the PV power systems performed very well with loads from only two systems experiencing outages due to the PV power system. Photovoltaic system availability was an estimated 20 to 60% for the Donguila and Onguia village lights and 100% for all the other types of systems. Although the availability of the photovoltaic power systems was high, there were many component failures in the control subsystems which did not materially affect system performance.

Loads availability varied widely depending on the type of appliance. Fluorescent light assemblies had the lowest availability with nearly all of the original inverter/ballast failing by the end of the first year of systems operation. Over half of the total number of pump motors installed in the first year of operation (originals plus replacements) failed. There were component failures in 50% of the vaccine refrigerators which reduced their combined availability to about 80%. Additionally, there were problems with the low pressure sodium vapor lamps and their inverter/ballasts and with light timer switches.

Although the vaccine refrigerators functioned reasonably well and there were TV's/VCR's, the ministry of health did not have an extended program for immunization which could have used the refrigerators as intended, and the ministry of education did not have instructional classroom material for use with TV's and VCR's. The water systems were particularily welcomed, especially in the village of Dongulia where there is a large boarding school and where the previous water source was incredibly inadequate and difficult to access.

As with innumerable other photovoltaic installations, the photovoltaic modules are the most reliable system component and the load devices are the least reliable system component. All of the equipment problems which developed during the year of operational support following installation have been remedied. Future efforts should be directed at improving the reliability of load devices suitable for use with PV systems.

The performance of these community service type systems has stimulated public and private sector interest in additional PV systems.

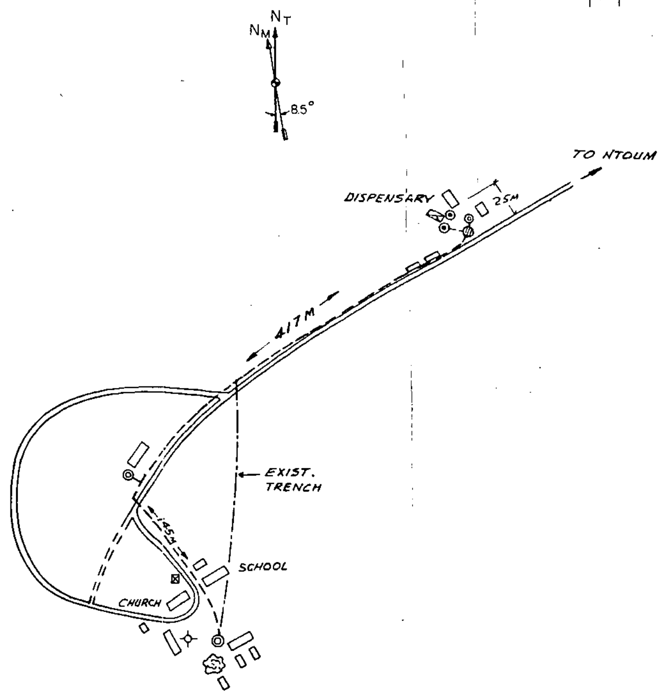
A P P E N D I X   A

TITLE	DRAWING NUMBER	REVISION
DONGUILA VILLAGE PLAN	79CSB28001B	A
BOLOSSOVILLE VILLAGE PLAN	79CSB28051B	0
ONGUIA-BOUGANDJI VILLAGE PLAN	79CSB28016B	A
NYALI VILLAGE PLAN	79CSB28034B	A
PV SYSTEM ARRAY SUPPORT ASSEMBLY - 20 MODULE	01DSB28095B	0
BATTERY ENCLOSURE	16DSB28109B	0
DISPENSARY SYSTEM - PV SYSTEM INSTRUMENTS AND CONTROLS ASSEMBLY	01DSB28084B	A
DISPENSARY SYSTEM - PV SYSTEM INSTRUMENTS AND CONTROLS PANEL LAYOUT	79CSB28086B	B
WATER SYSTEM - HORIZONTAL WATER STORAGE TANK	81BSB28100B	A
DONGUILA WATER SYSTEM - DISTRIBUTION PLAN	79CSB28012B	B
WATER SYSTEM - FOUNTAIN ASSEMBLY	01BSB28099B	0
VILLAGE LIGHT SYSTEM - PV SYSTEM ASSEMBLY	01DSB28101B	C
BOLOSSOVILLE DISPENSARY SYSTEM - PV SYSTEM SITE PLAN	79CSB28052B	C
BOLOSSOVILLE DISPENSARY SYSTEM - PV SYSTEM WIRING DIAGRAM	69CSB28053B	C
DISPENSARY SYSTEM - PV SYSTEM SCHEMATIC	63DSB28083B	A
BOLOSSOVILLE SCHOOL SYSTEM - PV SYSTEM SITE PLAN	79CSB28057B	B

REVISIONS					
REV.	ECO NO.	CHANGE	DATE	BY	ENGR.
O		INITIAL RELEASE	2-9-84	RC	WJK
A		REVISE WELL AND TANK LOCATION	6-7-85	JMZ	BK

LEGEND

- WATER TANK
- WATER WELL
- WATER FOUNTAIN
- WATER DISTRIBUTION
- MAIN ROAD
- ACCESS ROAD
- PV ARRAY
- BUILDING
- VILLAGE LIGHT



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ECHELLE: 1/2500

0 50 100 M

(1 CM = 25M)

2 FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L. SPEC.
4	1	01DSB28101B	PV SYSTEM ASSY-VILLAGE	LIGHT SYSTEM
3	1	79CSB28012B	WATER SYSTEM DISTRIBUTION PLAN	
2	1	79CSB28007B	PV SYSTEM SITE PLAN	SCHOOL SYSTEM
1	1	79CSB28002B	PV SYSTEM SITE PLAN, DISPENSARY & WATER SYSTEM	

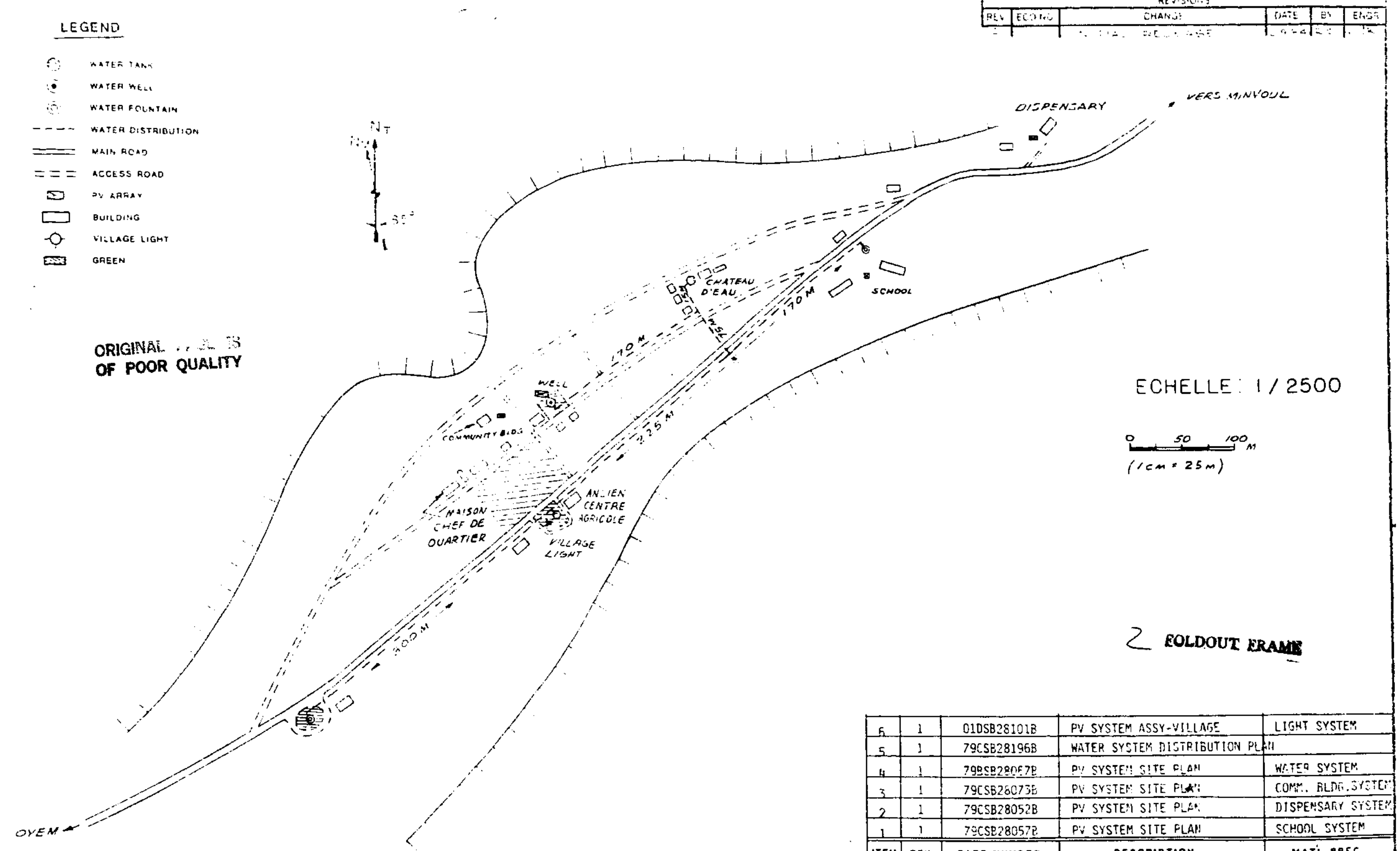
BILL OF MATERIALS

SOLAVOLT INTERNATIONAL

TITLE: DONGUILA VILLAGE PLAN

DRAWN BY RWC	DATE 11-15-83	SIZE C	DRAWING NO. 79CSB28001B
CHECKED BY	DATE	SCALE 1/2500	WEIGHT
ENGR. APPROVAL	DATE	SHEET 1 OF 1	

1 FOLDOUT FRAME



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2 FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L.SPEC.
6	1	01DSB28101B	PV SYSTEM ASSY-VILLAGE	LIGHT SYSTEM
5	1	79CSB28196B	WATER SYSTEM DISTRIBUTION PLAN	
4	1	79BSB28067B	PV SYSTEM SITE PLAN	WATER SYSTEM
3	1	79CSB28073B	PV SYSTEM SITE PLAN	COMM. BLDG.SYSTEM
2	1	79CSB28052B	PV SYSTEM SITE PLAN	DISPENSARY SYSTEM
1	1	79CSB28057B	PV SYSTEM SITE PLAN	SCHOOL SYSTEM

BILL OF MATERIALS

MATERIAL

SOLAVOLT Silicon Division

QTY REQ'D

TITLE

BOLOBBOVILLE

VILLAGE PLAN

APPLIED FINISH

DRAWN BY Russ C DATE

CHECKED BY DATE

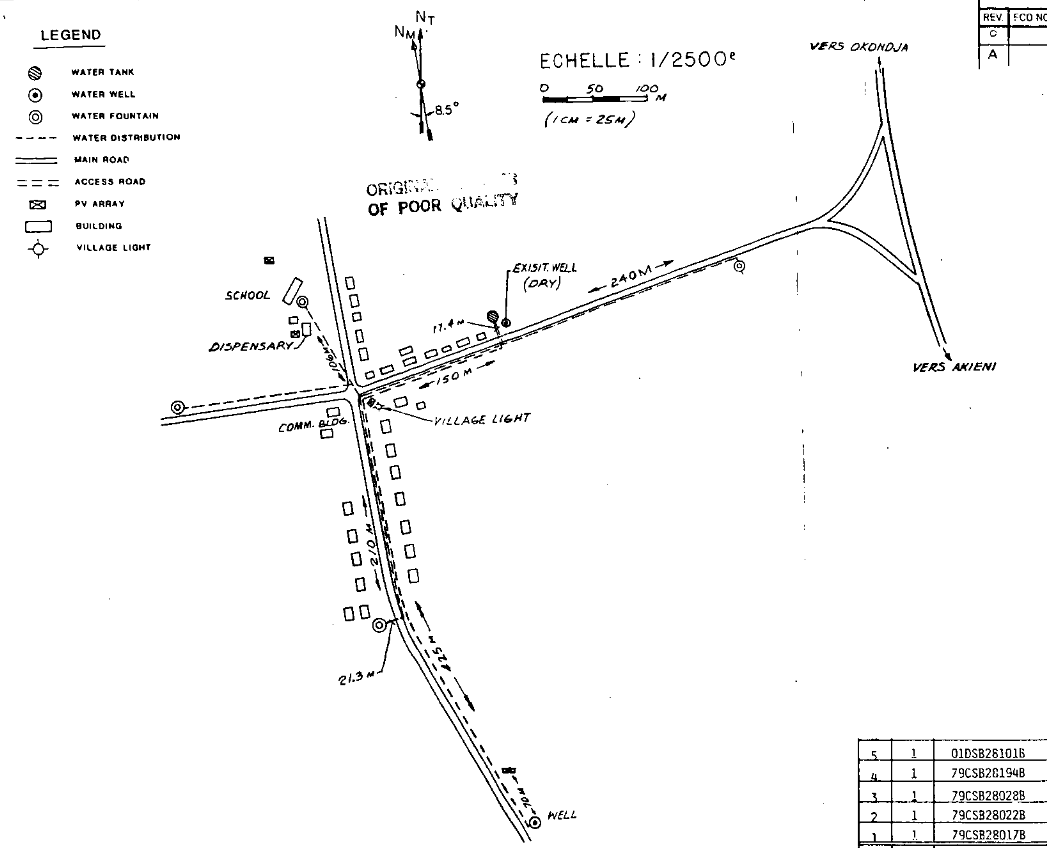
ENGR APPROVAL DATE

SIZE C DRAWING NO 79CSB28051B

SCALE 1/2500 WT GHT SHEET 1 OF 1

1 FOLDOUT FRAME

REVISIONS					
REV	ECO NO.	CHANGE	DATE	BY	ENGR.
O		INITIAL RELEASE	2-9-84	RC	WJK
A		SEPARATE PIPE FROM WELL TO TANK.	6-4-85	JMZ	BK



FOLDOUT FRAME

FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L.SPEC.
5	1	01DSB28101B	PV SYSTEM ASSY-VILLAGE	LIGHT SYSTEM
4	1	79CSB28194B	WATER SYSTEM DISTRIBUTION PLAN	
3	1	79CSB28028B	PV SYSTEM SITE PLAN	WATER SYSTEM
2	1	79CSB28022B	PV SYSTEM SITE PLAN	SCHOOL SYSTEM
1	1	79CSB28017B	PV SYSTEM SITE PLAN, DISPENSARY SYSTEM	

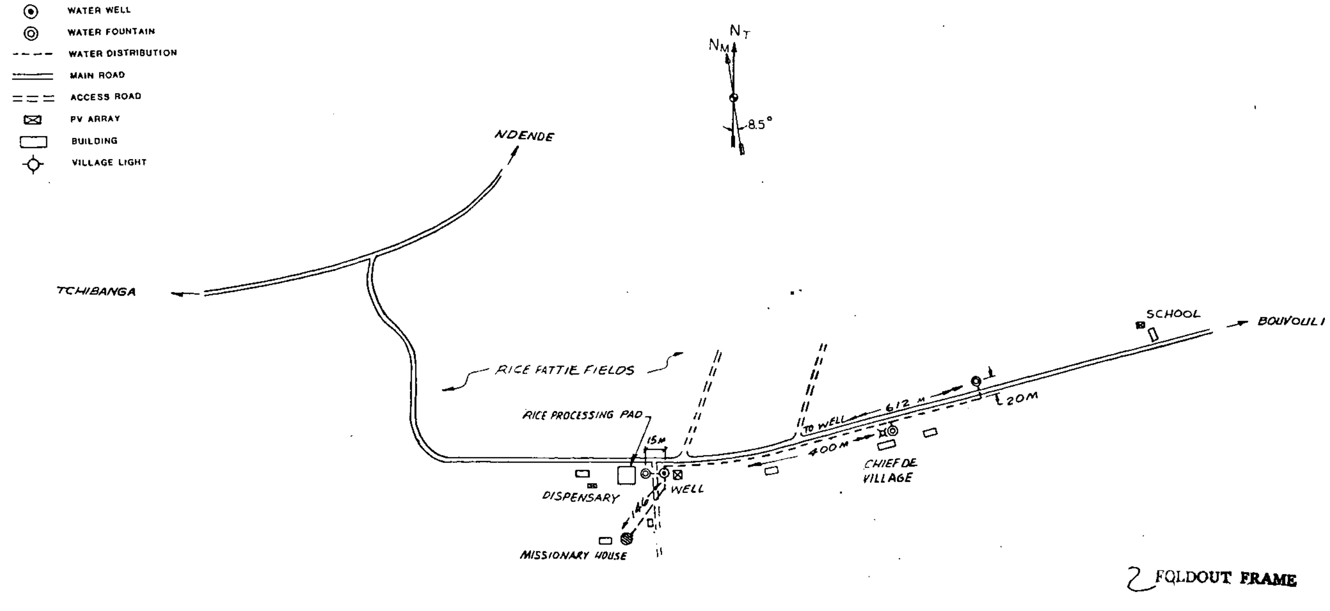
BILL OF MATERIALS

SOLAVOLT INTERNATIONAL

TITLE: ONGUIA—BOUGANDJI VILLAGE PLAN

DRAWN BY: Russ C	DATE: 1-14-83	SIZE: C	DRAWING NO.: 79CSB28016B
CHECKED BY:	DATE:		
ENGR APPROVAL: W. Kusza	DATE: 2/7/84	SCALE: 1/2500	WEIGHT:	SHEET 1 OF 1

REVISIONS					
REV.	ECO NO	CHANGE	DATE	BY	ENGR.
0		INITIAL RELEASE	2-9-84	RC	WJK
A		ADDED WATER FOUNTAIN	6-3-85	JMZ	BK



FOLDOUT FRAME

5	1	01DSB28101B	PV SYSTEM ASSY-VILLAGE LIGHT SYSTEM	
4	1	79CSB28195B	WATER SYSTEM DISTRIBUTION PLAN	
3	1	79BSB28054B	PV SYSTEM SITE PLAN	WATER SYSTEM
2	1	79CSB28040B	PV SYSTEM SITE PLAN	SCHOOL SYSTEM
1	1	79CSB28035B	PV SYSTEM SITE PLAN	DISPENSARY SYSTEM
ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L.SPEC.

BILL OF MATERIALS

SOLAVOLT INTERNATIONAL

TITLE: NYALI VILLAGE PLAN

DRAWN BY Russ C.	DATE 11-15-[illegible]	SIZE C	DRAWING NO. 79CSB28034B
CHECKED BY	DATE		
ENGR APPROVAL W. Kunzen	DATE [illegible]/84	SCALE 1/5000	WEIGHT / SHEET 1 OF 1

FOLDOUT FRAME

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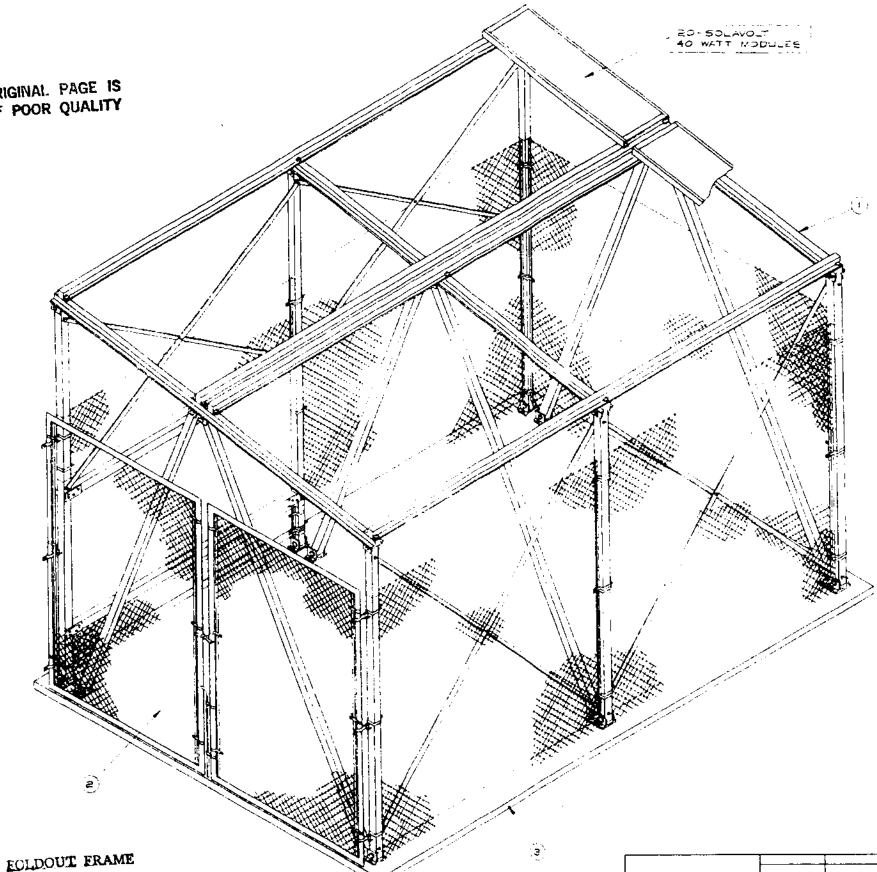
OF POOR QUALITY



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GENERAL PROVISIONS

1. THESE DRAWINGS DETAIL ALL ASPECTS OF THE INSTALLATION OF AN ELEVATED SUPPORT STRUCTURE [illegible] TWENTY (20) SOLAVOLT 40 WATT [illegible] MODULES.
2. THE FRONT HEIGHT OF THE ARRAY [illegible] (NOMINAL). THE PANEL ARRAY IS TILTED AT AN ANGLE OF [illegible] (NOMINAL) AND FACES NORTH.
3. THE DESIGN INCLUDES A STANDARD CHAIN LINK FENCE [illegible] IN HEIGHT [illegible] ALLOWABLE GATE.
4. ALL CONSTRUCTION WORK SHALL BE IN CONFORMANCE WITH ALL LOCAL CODES AND REGULATIONS [illegible] STANDARDS AND ANY OTHER APPLICABLE REGULATORY AGENCIES. IN THE EVENT OF DISCREPANCY BETWEEN THESE DRAWINGS AND SUCH CODES OR REGULATIONS, THE MORE STRINGENT METHOD OR TECHNIQUE SHALL GOVERN.
5. ALL MATERIALS USED IN THE FABRICATION AND INSTALLATION OF THE SUPPORT ASSEMBLY MUST BE IN ACCORDANCE WITH THESE DRAWINGS.
6. [illegible]
7. [illegible]
8. FENCING COMPONENTS: [illegible] STANDARD GALVANIZED STEEL [illegible] PARTS IN CONTACT WITH ALUMINUM [illegible] COATED TO MINIMIZE [illegible]
9. ANCHOR BOLTS: [illegible] AND COMES COMPLETE WITH NUT AND WASHER.
10. CONCRETE: CONCRETE SHALL BE [illegible] A COMPRESSIVE STRENGTH OF AT LEAST [illegible] ACI STANDARDS [illegible] EQUAL.
11. REINFORCING BARS: [illegible] DEFORMED BILLET STEEL [illegible]

2 FOLDOUT FRAME

ITEM	ASSY. #	DESCRIPTION	QTY.
3	01D5B28116B	CONCRETE PAD	1
2	01D5B28115B	FENCING ASSY. (20 PANEL)	1
1	01D5B28114B	SUPPORT STRUCTURE ASSY (20 PANEL)	1

PARTS LIST

SEE NOTE #7

AS REQUIRED

SEE NOTE #7

SOLAVOLT Silicon Division

PV SYSTEM ARRAY SUPPORT ASSEMBLY - 20 MODULE

D 01D5B28[illegible]

1 FOLDOUT FRAME

REV	ECO NO	CHANGE	DATE	BY	ENGR
A		INITIAL RELEASE		JE	

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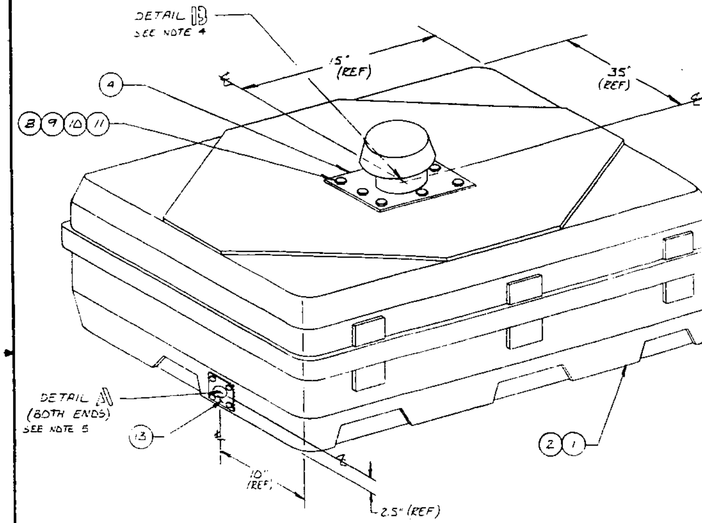

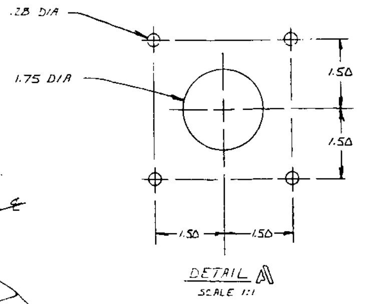

DETAIL A
SCALE 1:1

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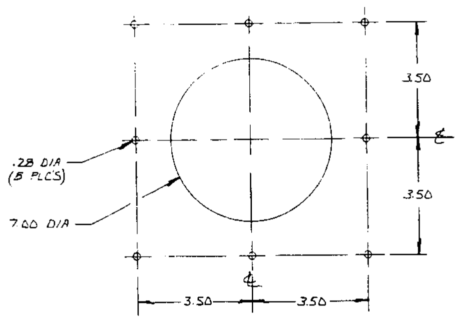


DETAIL B
SCALE 1:2

2 FOLDOUT FRAME

FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L SPEC.
20				
19				
18				
17	1		PADLOCK	
16	1	SSMA0278	EYE WASH STATION	
15	1	SSTK0277	HYDROMETER	
14	2	1 1/4"	KNOCKOUT PLUG	
13	2	6483828236B	CONDUIT MTG PLATE	
12	2	SSM0285	SEALANT, SILICON RUBBER	
11	12	1/4"	LOCK WASHER	
10	24	1/4"	FLAT WASHER	
9	12	1/4-20	HEX NUT	
8	12	1/4-20 × 3/4"	BOLT HEX HEAD	
7	2 PAIR	TB200200058	GLOVES, LATEX MEDIUM PAIR	
6	1	TB200120009	APRON, PLASTIC 48"	
5	2GAL		DEIONIZED WATER	
4	1	10 FR	ROOF VENT	PENN
3	2	HRH	FUSE, IN-LINE	BUSS
2	1	951103	STORAGE POD, 36" × 60"	A4E
1	1	951104	STORAGE POD, 36" × 78"	A4E

BILL OF MATERIALS

5. MODIFY EACH END OF ENCLOSURE BASE PER DETAIL 'A' (CONDUIT ENTRANCE). USE ITEM (14) TO PLUG HOLES.
4. MODIFY COVER PER DETAIL 'B' (HOLE PATTERN FOR VENT). MOUNT ITEM (4) USING SILICON RUBBER SEALANT TO SEAL VENT FLANGE TO ENCLOSURE.
3. ITEMS (3) THRU (17) TO BE PACKED INSIDE ENCLOSURE PRIOR TO SHIPPING.
2. ITEMS [illegible] NOT SHOWN.
1. USE ITEM [illegible] FOR ALL VILLAGES EXCEPT BOLOSSOVILLE. USE ITEM [illegible] FOR VILLAGE OF BOLOSSOVILLE.

NOTES:

SOLAVOLT INSPECTION PLAN

USED ON | NO. REQ'D ASSY
APPLICATION

UNLESS OTHERWISE SPECIFIED TOLERANCES
INCHES .XX ± .XXX ±
MILLIMETERS X ± .X ±
ANGULAR ±
RMS ALL MACHINED SURFACES
FEATURE CONTROL SYMBOLS PER ANSI Y14.5
BREAK ALL SHARP EDGES AND CORNERS REMOVE BURRS
UNDERLINED DIM NOT TO SCALE
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED

MATERIAL

QTY REQ'D

APPLIED FINISH

DRAWN BY C. FREITE | DATE
CHECKED BY | DATE
ENGR APPROVAL

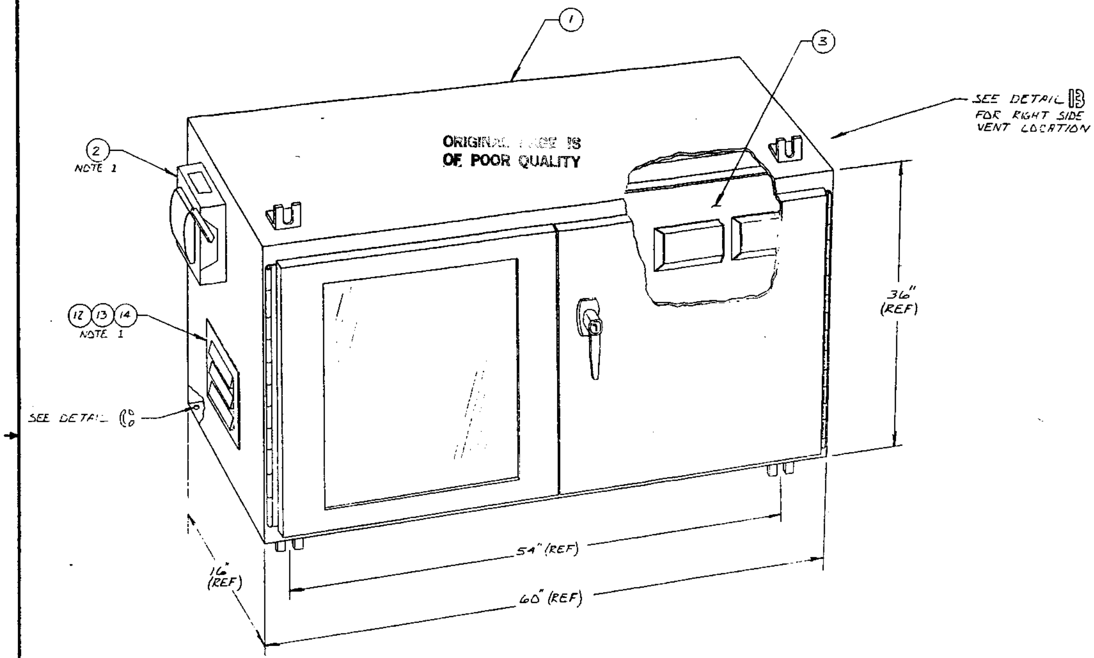
SOLAVOLT Silicon Division

TITLE BATTERY ENCLOSURE

SIZE D | DRAWING NO. [illegible]

SCALE | WEIGHT | SHEET

REVISIONS					
REV	ECO NO	CHANGE	DATE	BY	ENGR
O		INITIAL [illegible]	[illegible]		[illegible]
A		ADDED ITEMS 7–15, NOTE 3&4 & DETAIL [illegible], CHANGED NOTE [illegible], DETAIL A [illegible]	JE	[illegible]	



FOLDOUT FRAME

FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L SPEC.
15	1		LABEL, SOLAVOLT LOGO	
14	4'	1/2" WIDE	TAPE–FOAM 1/8" THK	BLACK
13	2	5-1/2" SQ	SCREEN–GREY	PLASTIC
12	2	AVK44	LOUVER PLATE KIT	W/HARDWARE
11	4	3/8	LOCK WASHER	STN. STL.
10	8	3/8	FLAT WASHER	STN. STL.
9	4	3/8-16	HEX NUT	STN. STL.
8	4	3/8-16 × 3 1/4"	BOLT, HEX HEAD	STN. STL.
7	11	1/4	LOCK WASHER	
6	22	1/4	FLAT WASHER	
5	11	1/4-20	HEX NUT	
4	11	1/4-20 × 3/4"	BOLT, HEX HEAD	
3	1	79CSB28086B	INSTRUMENT & CONTROL PANEL LAYOUT	
2	1	SSWT0269	DISCONNECT, 60A	
1	1	36 × 60 × 16	ENCLOSURE	

BILL OF MATERIALS

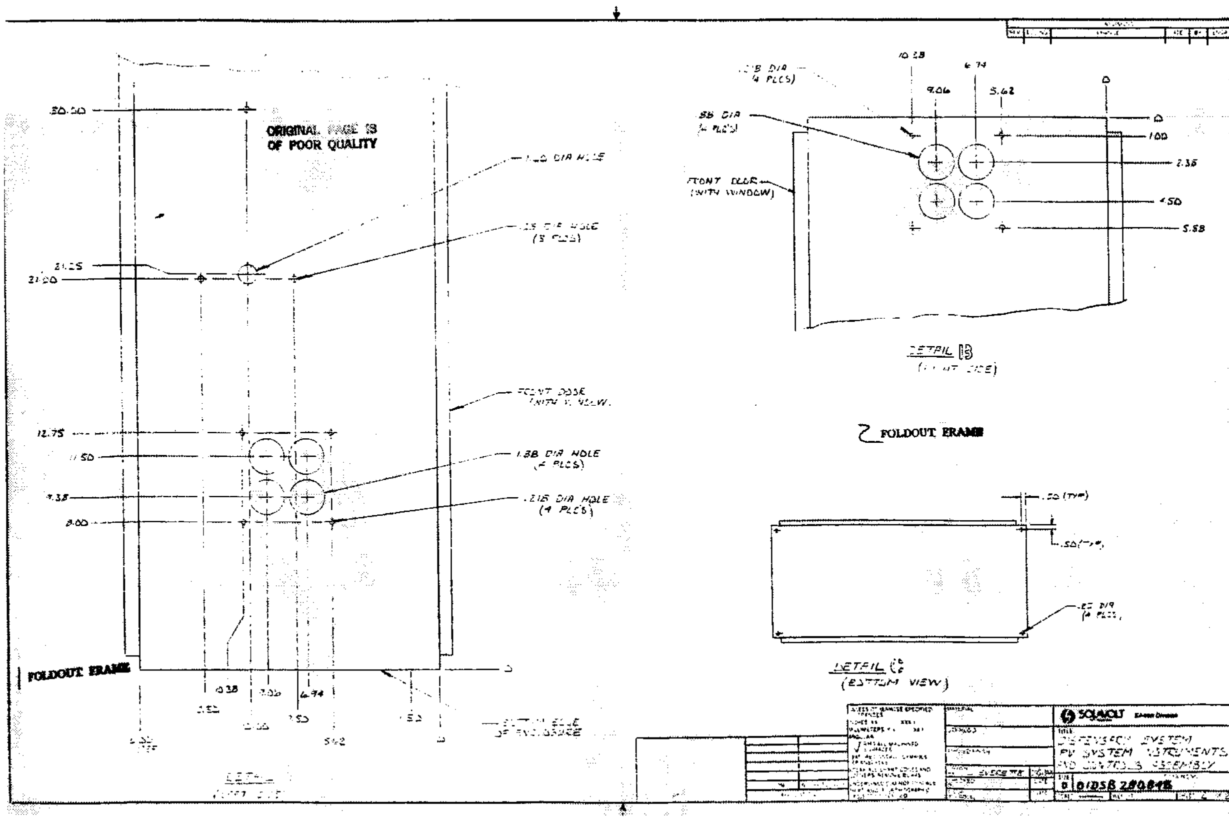
NOTES:

4. ITEMS [illegible] NOT SHOWN [illegible]
3. [illegible]
2. ITEMS (& [illegible]) TO BE [illegible] INSIDE ENCLOSURE.
1. LOCATE MOUNTING HOLES FOR DISCONNECT AND [illegible] ON LEFT SIDE [illegible] DETAIL A ON SHEET 2.

USED ON	NO REQ'D ASSY
APPLICATION	

UNLESS OTHERWISE SPECIFIED
TOLERANCES
INCHES .XX ± .02 .XXX ± .01
MILLIMETERS .X ± .XX ±
ANGULAR ±
√ RMS ALL MACHINED SURFACES
FEATURE CONTROL SYMBOLS PER ANSI Y14.5
BREAK ALL SHARP EDGES AND CORNERS REMOVE BURRS
UNDERLINED DIM NOT TO SCALE
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED

MATERIAL		SOLAVOLT Silicon Division	
QTY REQ'D		TITLE: DISPENSARY SYSTEM PV SYSTEM INSTRUMENTS AND CONTROL ASSEMBLY	
APPLIED FINISH			
DRAWN BY J. EVERETTE	DATE 2-6-84	SIZE D	DRAWING NO 01DSB28084B
CHECKED BY	DATE	SCALE — WEIGHT	SHEET 1 OF 2
ENGR APPROVAL	DATE		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FOLDOUT FRAME
1.38 DIA HOLE
(4 PLCS)
.218 DIA HOLE
(4 PLCS)
FRONT DOOR
(WITH WINDOW)
.88 DIA
(4 PLCS)
DETAIL B
DETAIL C
(BOTTOM VIEW)
30.00
21.25
21.00
12.75
11.50
9.38
8.00
10.38
7.06
6.94
2.50
10.88
9.06
5.62
1.00
2.38
4.50
5.88
.50 (TYP)
SOLAVOLT
PV SYSTEM
D

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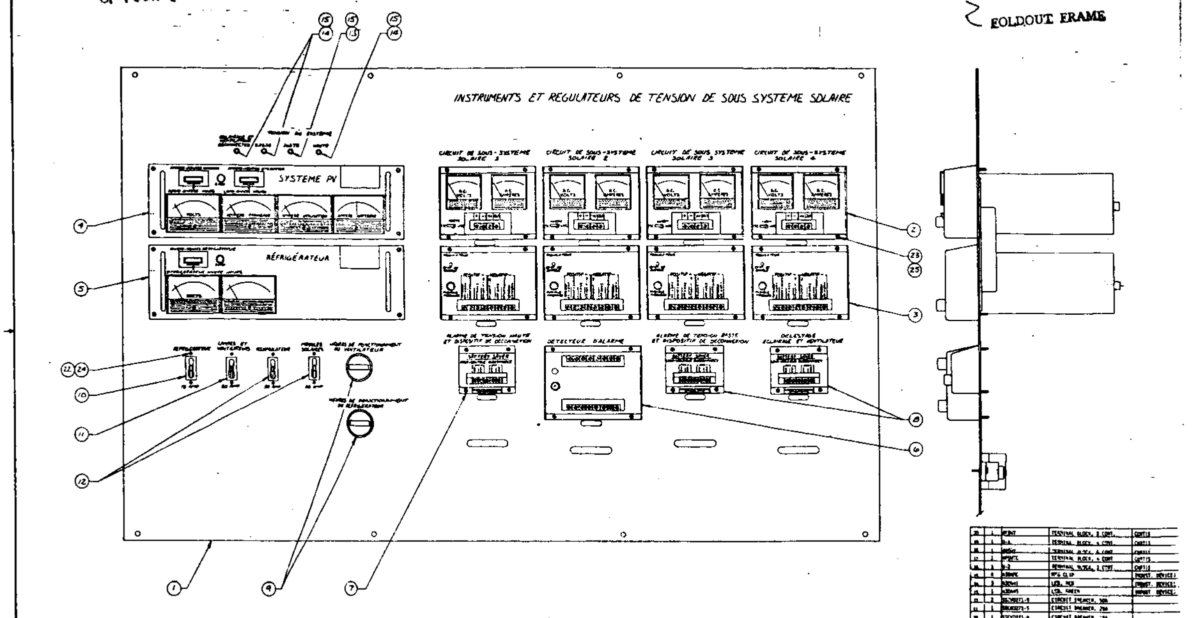
FOLDOUT FRAME



FOLDOUT FRAME

34	4	#10	FLAT WASHER	
33	6	#10	LOCK WASHER	
32	2	10-32	HEX NUT	
31	2	[illegible]	SCREW, PAN HEAD	
30	2	[illegible]	CHANNEL CLAMP	BUCHANAN
29	[illegible]	[illegible]	[illegible]	
28	[illegible]	[illegible]	[illegible]	
27	6	[illegible]	JUMPER	
26	11	[illegible]	TERMINAL BLOCK	BUCHANAN
25	[illegible]	[illegible]	FLAT WASHER	
24	8	#6	FLAT WASHER	
23	[illegible]	[illegible]	SCREW, SELF TAPPING	
[illegible]	[illegible]	[illegible]	[illegible]	
ITEM	QTY	PART NUMBER	DESCRIPTION	MATL SPEC

20	1	[illegible]	TERMINAL BLOCK, 3 CONT.	CURTIS
19	1	[illegible]	TERMINAL BLOCK, 4 CONT.	CURTIS
18	1	[illegible]	TERMINAL BLOCK, 6 CONT	CURTIS
17	1	[illegible]	TERMINAL BLOCK, 4 CONT	CURTIS
16	1	[illegible]	TERMINAL BLOCK, 2 CONT.	CURTIS
15	4	[illegible]	LED CLIP	INDUST. DEVICES
14	3	[illegible]	LED, RED	INDUST. DEVICES
13	1	[illegible]	LED, GREEN	INDUST. DEVICES
12	2	[illegible]	CIRCUIT BREAKER, 50A	
11	1	[illegible]	CIRCUIT BREAKER, 20A	
10	1	[illegible]	CIRCUIT BREAKER, 15A	
9	2	[illegible]	RUN TIME METER	
8	2	[illegible]	LOW VOLTAGE DISCONNECT	
7	2	[illegible]	HIGH VOLTAGE DISCONNECT	
6	1	[illegible]	ALARM CIRCUIT CARD	
5	1	[illegible]	R/F INSTR.	
4	1	[illegible]	ARRAY/LOAD INSTR., 20A	
3	4	[illegible]	VOLTAGE REGULATOR	
2	4	[illegible]	ARRAY METER, GENERAL	
1	1	[illegible]	INSTRU. & CNTL PANEL	
ITEM	QTY	PART NUMBER	DESCRIPTION	MATL SPEC

BILL OF MATERIALS

SOLAVOLT

DISPENSARY SYSTEM PV SYSTEM INSTRUMENTS AND CONTROLS PANEL LAYOUT

NOTES:

1. MOUNT TERMINAL BLOCKS ON REAR SIDE OF PANEL.
2. USE 10-32 PAN HEAD SCREWS & #10 FLAT WASHERS TO MOUNT CIRCUIT BREAKERS TO PANEL.
3. NYLON NUTS [illegible] NOT SHOWN, INSTALL BY PUSHING INTO SQUARE HOLES. USE SELF TAPPING SCREWS [illegible] TO ATTACH COMPONENTS TO PANEL [illegible] NYLON NUTS.

REVISIONS

REV.	ECO NO.	CHANGE	DATE	BY	ENGR.

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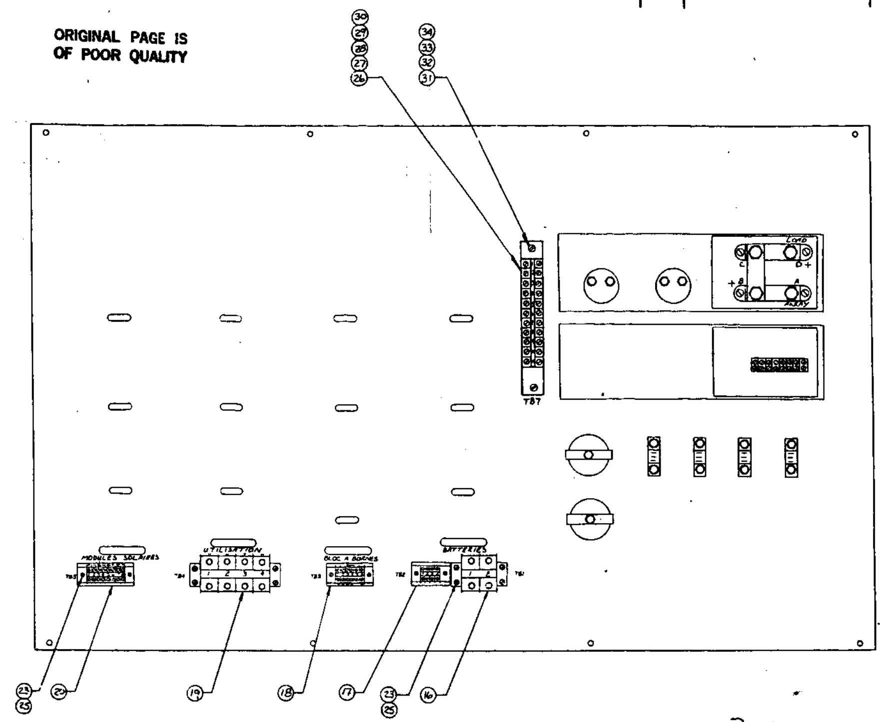
OF POOR QUALITY



REAR VIEW

1 FOLDOUT FRAME

2 FOLDOUT FRAME

USED ON	NO. REQ'D/ASSY
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
INCHES .XX ± .XXX ±
MILLIMETERS .X ± .XX ±
ANGULAR ±
√ RMS ALL MACHINED SURFACES.
FEATURE CONTROL SYMBOLS PER ANSI Y14.5
BREAK ALL SHARP EDGES AND CORNERS, REMOVE BURRS.
UNDERLINED DIM NOT TO SCALE
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED

MATERIAL

QTY REQ'D

APPLIED FINISH

DRAWN BY J. EVERETTE — DATE 2-23-84
CHECKED BY — DATE
ENGR APPROVAL — DATE

SOLAVOLT INTERNATIONAL Silicon Division

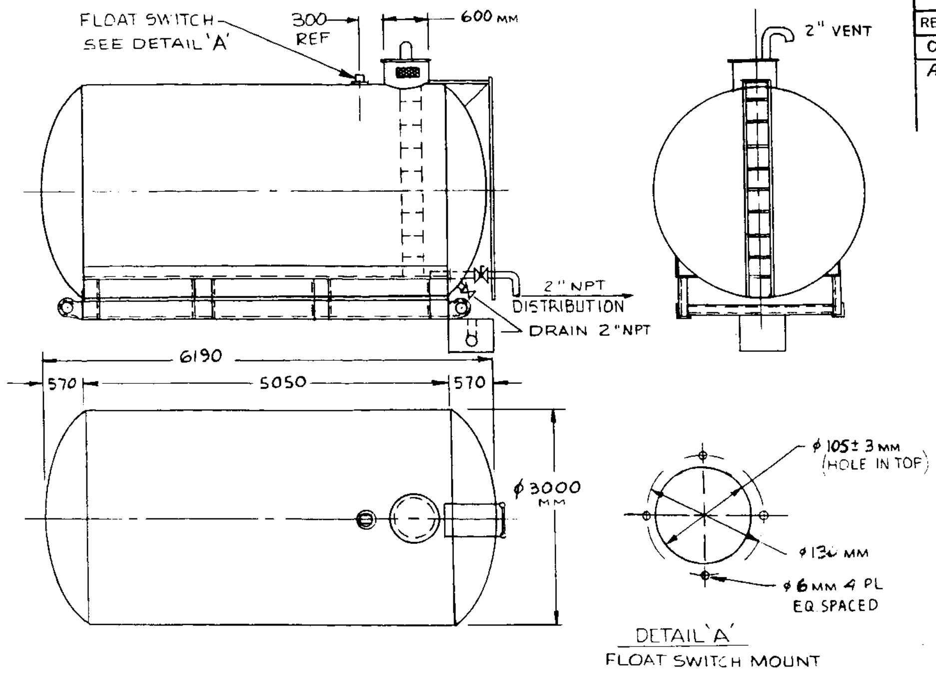
TITLE:
DISPENSARY SYSTEM
PV SYSTEM INSTRUMENTS AND
CONTROLS PANEL LAYOUT

SIZE C — DRAWING NO. 79CSB28086B

SCALE — WEIGHT — SHEET 2 OF 2

84135

REVISIONS					
REV.	ECO NO.	CHANGE	DATE	BY	ENGR.
O		INITIAL RELEASE	1-17-84		WJK
A		CHANGED DETAIL 'A'	4-25-84	JE	



DETAIL 'A'
FLOAT SWITCH MOUNT

FOLDOUT FRAME

NYALI	20,000 ℓ
ONGUIA BOUGANDJI	20,000 ℓ
BOLOSSOVILLE	30,000 LITERS
VILLAGE	CAPACITY ℓ

FOLDOUT FRAME

79BSB28028B	
79BSB28045B	
79BSB28067B	
USED ON	NO. REQ'D/ASSY
APPLICATION	

UNLESS OTHERWISE SPECIFIED
TOLERANCES
INCHES .XX · XXX ·
MILLIMETERS .X · XX ·
ANGULAR ·
√ RMS ALL MACHINED SURFACES
FEATURE CONTROL SYMBOLS PER ANSI Y14.5
BREAK ALL SHARP EDGES AND CORNERS. REMOVE BURRS
UNDERLINED DIM NOT TO SCALE
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED

DRAWN BY Russ C.	DATE 1-11-84
CHECKED BY	DATE 1/6/84
ENGR APPROVAL	DATE

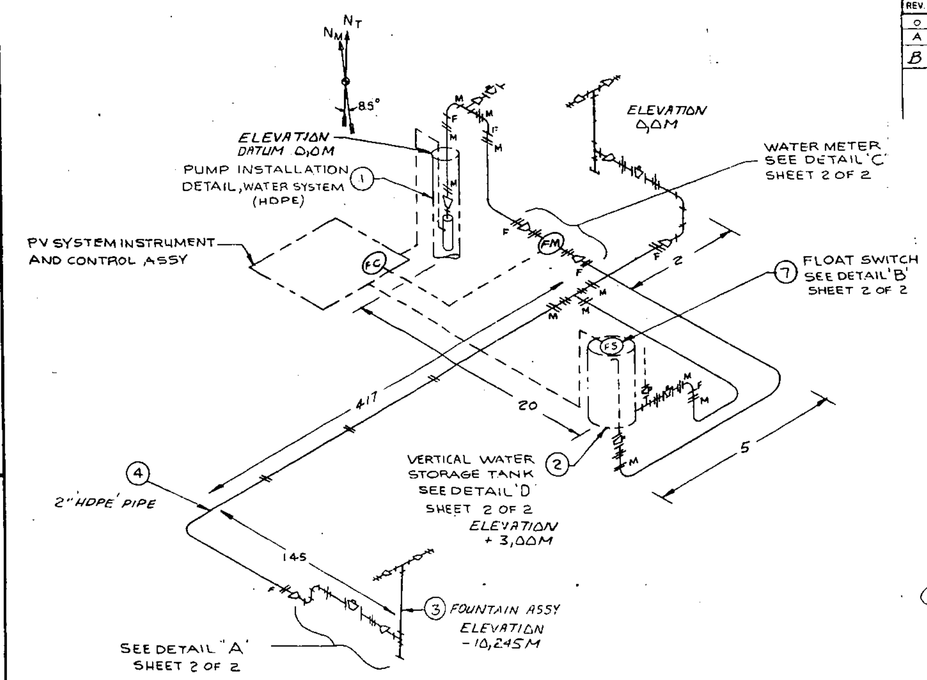
SOLAVOLT INTERNATIONAL

TITLE
WATER SYSTEM
HORIZONTAL
WATER STORAGE TANK

SIZE B | DRAWING NO. 81BSB28100B

SCALE NONE | WEIGHT | SHEET 1 OF 1

REVISIONS					
REV.	ECO NO	CHANGE	DATE	BY	ENGR
O		INITIAL RELEASE	2-9-84	RC	WJK
A		REVISED DETAIL 'D' NEW TANK	3-23-84		
B		ADDED ELEVATIONS	4-13-84	JE	



ORIGINAL PAGE IS OF POOR QUALITY

FOLDOUT FRAME

FOLDOUT FRAME

6. APPLY TEFLON TAPE TO ALL PIPE FITTINGS.
5. SEE SHEET 2 OF 2 FOR BILL OF MATERIALS.
4. PIPE TO BE BURIED 60-80 cm DEEP, ROAD CROSSINGS 1 m DEEP.
3. ALL CONTROL WIRING IS BURIED IN PIPE TRENCH.
2. PIPE TO BE HDPE 160 PSI (HIGH DENSITY POLYETHYLENE).
1. DIMENSIONS ARE IN METERS, SHOWING PIPE LENGTHS.

NOTES:

	UNION		COUPLING-M.I.P.
	COUPLING, PE-PE		COUPLING-F.I.P.
	JOINT		FAUCET
	ELBOW 90°		PIPE
	STREET ELBOW 90°		CONTROL WIRING
	TEE	FM	FLOW METER
	REDUCER BUSHING	FC	FLOW COUNTER
	CORPORATION STOP	FS	FLOAT SWITCH

LEGEND

NEXT ASSY: 79CSB28001B

SOLAVOLT INTERNATIONAL

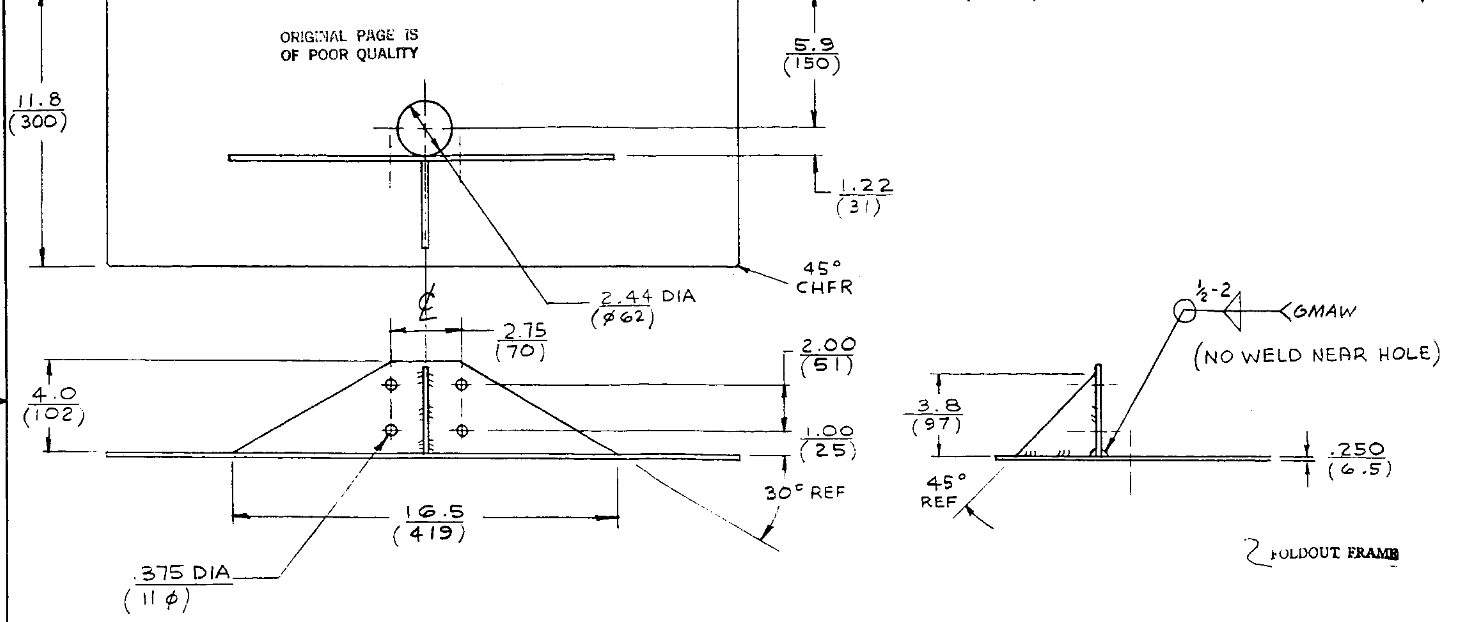
TITLE: DONGUILA WATER SYSTEM DISTRIBUTION PLAN

DRAWN BY Ross C. | DATE
CHECKED BY | DATE
ENGR APPROVAL | DATE

SIZE C | DRAWING NO. 79CSB28012B

SCALE NONE | SHEET 1 OF 2

REVISIONS					
REV.	ECO NO.	CHANGE	DATE	BY	ENGR.



2 FOLDOUT FRAME

1. DIMENSIONS DEPICTED THUS: INCH / (MM) .

NOTES:

1 FOLDOUT FRAME

USED ON	NO. REQ'D/ASSY
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
INCHES .X = .06 .XX ± .03
MILLIMETERS .X = 1MM .XX ±
ANGULAR =
√ RMS ALL MACHINED SURFACES.
FEATURE CONTROL SYMBOLS PER ANSI Y14.5.
BREAK ALL SHARP EDGES AND CORNERS. REMOVE BURRS.
UNDERLINED DIM NOT TO SCALE
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED

MATERIAL CARBON STEEL PLATE, 1/4" ASTM-A36

QTY REQ'D

APPLIED FINISH HOT DIP GALVANIZE ASTM-A-123

DRAWN BY	RWC	DATE 11 28 83
CHECKED BY		DATE
ENGR. APPROVAL	WJK	DATE 2/1/84

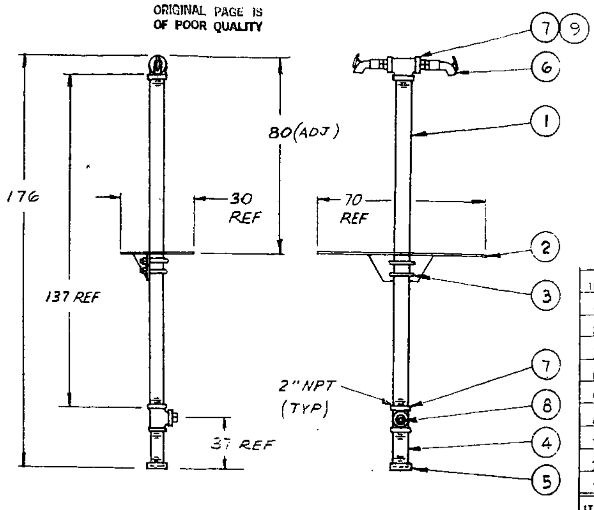
SOLAVOLT INTERNATIONAL

TITLE: WATER SYSTEM FOUNTAIN ASSY

SIZE B | DRAWING NO. 01BSB28099B

SCALE 1/4 | SHEET 2 OF 2

ORIGINAL PAGE IS
OF POOR QUALITY



REVISIONS					
REV	ECO NO	CHANGE	DATE	BY	ENGR
0		INITIAL RELEASE	2-1-84		WJK

2 FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L. SPEC.
10	A/R	SSMA0315	TAPE-PIPE SEAL	TEFLON
9	2	2" X 1/2" IPS	HEX BUSHING, SCHED. 40	GALV. STEEL
8	1	2" X 3/4" X 3/4" IPS	BUSHING - DOUBLE TAPPED	IRON
7	2	2" IPS	TEE - 150 LB, SCHED. 40	GALV. STEEL
6	2	1/2" IPS	FAUCET - SELF CLOSING	BRASS
5	1	2" IPS	PIPE CAP - SCHED. 40	GALV. STEEL
4	1	2" IPS X 30CM	PIPE NIPPLE - SCHED. 40	GALV. STEEL
3	2	2" IPS	U-BOLT ASSY, 5/16"-18	GALV. STEEL
2	1	SHT 2 OF 2	SHELF ASSY - FOUNTAIN	GALV. STEEL
1	1	2" IPS X 137CM	PIPE - SCHED. 40	GALV. STEEL

BILL OF MATERIALS

1 FOLDOUT FRAME

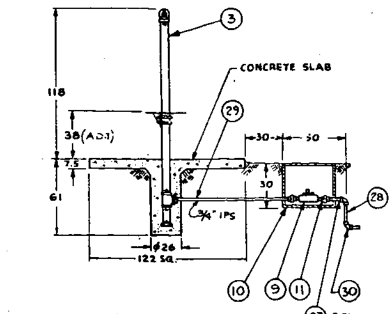
NEXT ASSY	SOLAVOLT INTERNATIONAL
SOLAVOLT INSPECTION PLAN: 62ASB28055B	TITLE: WATER SYSTEM - FOUNTAIN ASSEMBLY
DRAWN BY RUSS C. DATE 1/12/83	
CHECKED BY DATE	SIZE B DRAWING NO. 01BSB25099B
ENGR. APPROVAL WJK DATE 2/1/84	SCALE NONE SHEET 1 OF 2

NOTES:

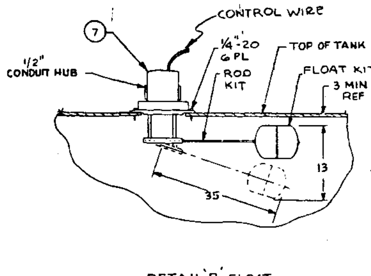
1. DIMENSIONS ARE IN CENTIMETERS.
2. ALL FITTINGS TO BE SCREW TYPE.
3. APPLY TEFLON TAPE TO ALL MALE FITTINGS.

REV.	ECO NO.	CHANGE	DATE	BY	ENGR.

ORIGINAL PAGE IS
OF POOR QUALITY



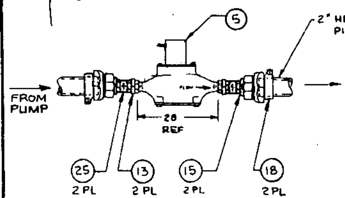
DETAIL 'A', WATER
FOUNTAIN INSTALLATION



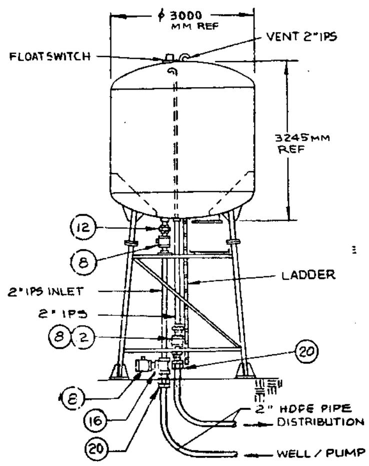
DETAIL 'B', FLOAT
SWITCH INSTALLATION

2 FOLDOUT FRAME

FOLDOUT FRAME



DETAIL 'C' WATER
METER INSTALLATION
(METER BOX NOT SHOWN)



DETAIL 'D', TANK INSTALLATION

ITEM	QTY.	PART NUMBER	DESCRIPTION	MATL. SPEC.
31	3	55MA0315	TAPE - PIPE SEAL	TEFLON
30	4	3/4" I.P.S.	ELBOW - 90°, SCHED. 40	GALV. STEEL
29	2	3/4" I.P.S. X 36"	PIPE NIPPLE, SCHED. 40	GALV. STEEL
28	2	3/4" I.P.S. X 12"	PIPE NIPPLE, SCHED. 40	GALV. STEEL
27	4	3/4" I.P.S. X 6"	PIPE NIPPLE, SCHED. 40	GALV. STEEL
26	5	2" I.P.S. X 2" LG	PIPE NIPPLE, SCHED. 40	GALV. STEEL
25	2	1" I.P.S. X 2" LG	PIPE NIPPLE, SCHED. 40	GALV. STEEL
24				
23				
22				
21	1/2 PC	IZOID	DEVCON 'Z'	COATING
20	8	C86-77-160	COUPLING - PE X NPT 2" (M)	PACK JOINT
19	18	C66-77-160	COUPLING - STRAIGHT PE	PACK JOINT
18	4	C16-77-160	COUPLING - PE X NPT 2" (F)	PACK JOINT
17	3	2" I.P.S., SCHED 40	ELBOW - STREET 90°	GALV. STEEL
16	4	2" I.P.S.	TEE - SCHED. 40	GALV. STEEL
15	3	2" X 1" I.P.S.	BUSHING - HEX, REDUCER	GALV. STEEL
14	4	2" X 3/4" X 3/4" IPS	BUSHING - DBL TAPPED	IRON
13	2	1" I.P.S.	UNION SCHED. 40	GALV. STEEL
12	6	2" I.P.S.	UNION SCHED. 40	GALV. STEEL
11	4	3/4" I.P.S.	UNION SCHED. 40	GALV. STEEL
10	3	H1017MB12M4C-2-BK	BOX - WATER METER	FRP
9	4	3/4" I.P.S. MALE	CORPORATION STOP, 125 PSI	BRASS
8	3	2" I.P.S. (MALE)	CORPORATION STOP, 125 PSI	BRASS
7	1	55WT0309	FLOAT SWITCH, NEMA 4 - ASSY	SO-D
6				
5	1	55C0253	WATER FLOW METER	REMOTE READOUT
4	21	2" I.P.S.	PIPE - 100 LIN FT COIL	HDPE - 125 PSI
3	2	01BSB28099B	FOUNTAIN ASSY	WATER SYSTEM
2	1	81BSB28015B	WATER STORAGE TANK,	VERTICAL
1	1	79CSB28005B	PUMP INSTALLATION DETAIL (HDPE)	WATER SYSTEM

BILL OF MATERIALS

NEXT ASSY: 79CSB28001B

SOLAVOLT INTERNATIONAL

TITLE: DONGUILA WATER SYSTEM DISTRIBUTION PLAN

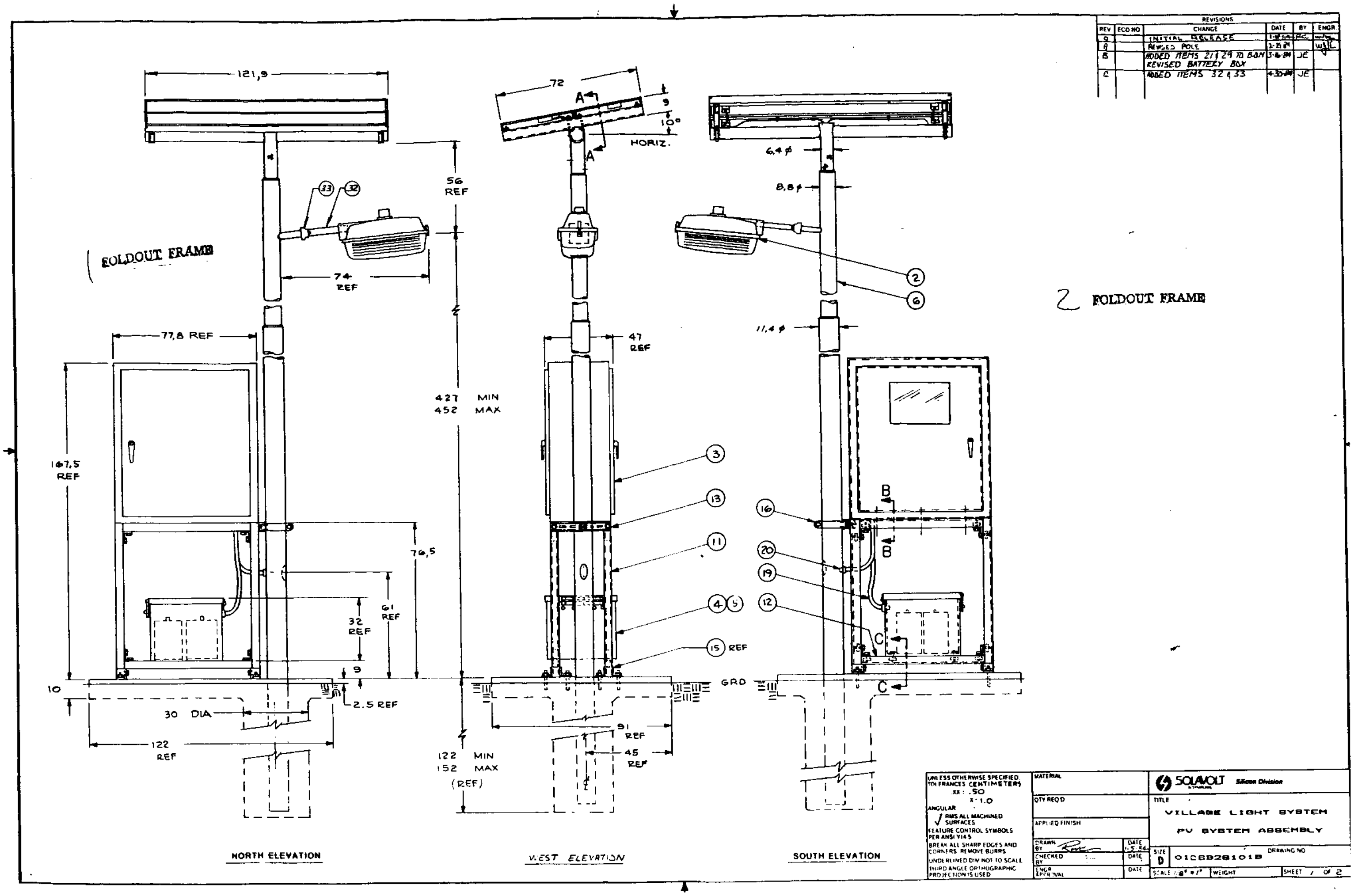
DRAWN BY	Rw	DATE	
CHECKED BY		DATE	
ENGR. APPROVAL		DATE	

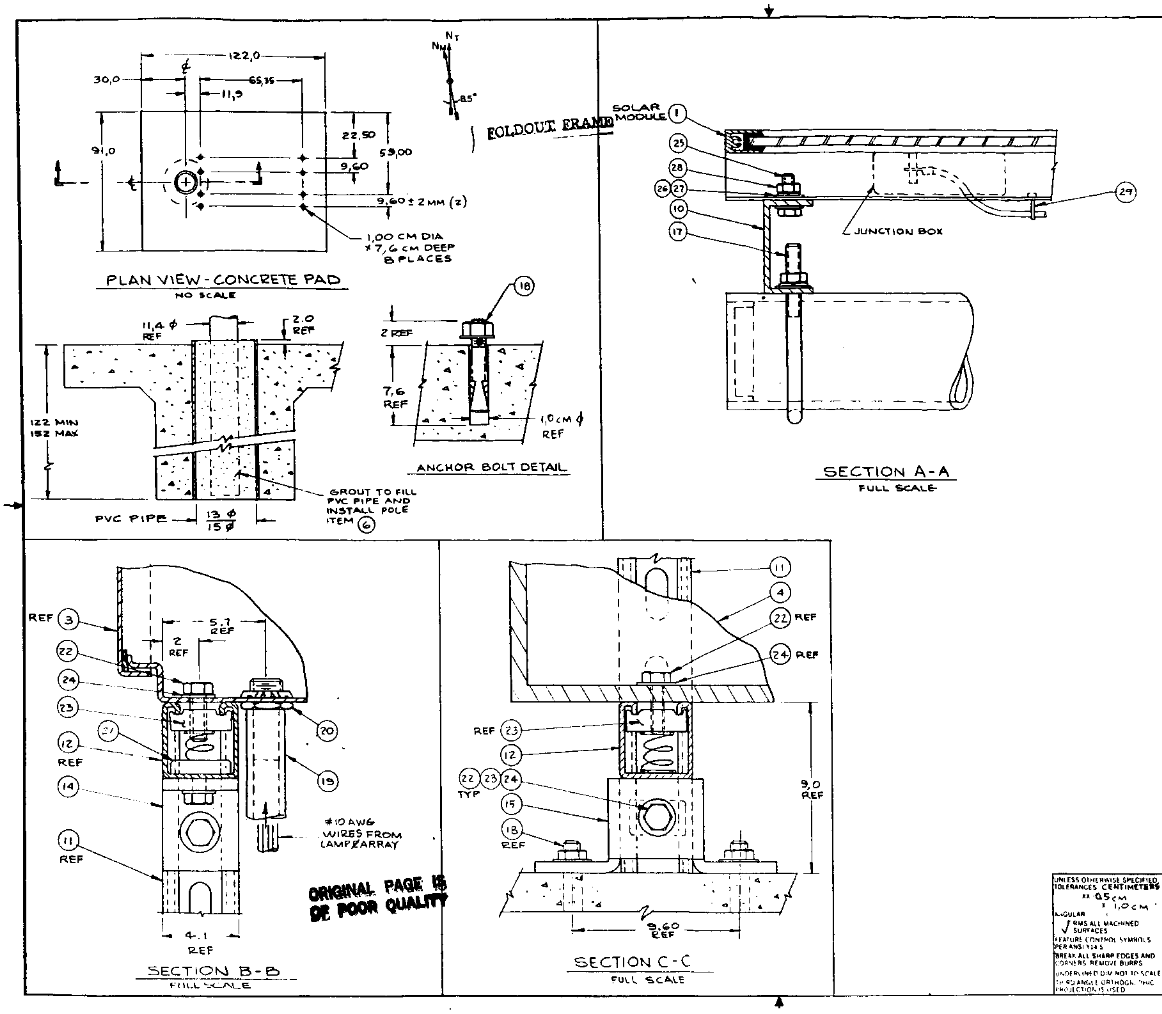
SIZE: C

DRAWING NO. 79CSB28012B

SCALE: NONE

SHEET 2 OF 2


REVISIONS
REV | ECO NO | CHANGE | DATE | BY | ENGR
O | | INITIAL RELEASE | | RC |
A | | REVISED POLE | | | WJK
B | | ADDED ITEMS 21 & 29 TO B&M REVISED BATTERY BOX | 3-6-84 | JE |
C | | ADDED ITEMS 32 & 33 | 4-30-84 | JE |
FOLDOUT FRAME
2 FOLDOUT FRAME
121,9
72
A
9
10°
HORIZ.
56 REF
74 REF
6,4 φ
8,8 φ
11,4 φ
77,8 REF
47 REF
427 MIN
452 MAX
167,5 REF
76,5
61 REF
32 REF
9
10
2.5 REF
30 DIA
122 REF
91 REF
45 REF
122 MIN
152 MAX
(REF)
GRD
B
C
15 REF
NORTH ELEVATION
WEST ELEVATION
SOUTH ELEVATION
UNLESS OTHERWISE SPECIFIED TOLERANCES CENTIMETERS
.XX: .50
.X: 1.0
ANGULAR
RMS ALL MACHINED SURFACES
FEATURE CONTROL SYMBOLS PER ANSI Y14.5
BREAK ALL SHARP EDGES AND CORNERS. REMOVE BURRS
UNDERLINED DIM NOT TO SCALE
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED
MATERIAL
QTY REQ'D
APPLIED FINISH
DRAWN BY
DATE
CHECKED BY
ENGR APPROVAL
SOLAVOLT
Silicon Division
TITLE
VILLAGE LIGHT SYSTEM
PV SYSTEM ASSEMBLY
SIZE D
DRAWING NO
01CB828101B
WEIGHT
SHEET 1 OF 2



2 FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L.SPEC.
33	1	1-1/4" × 1"	REDUCER - CONCENTRIC	GALV. STEEL
32	1	1 IPS × 12"	NIPPLE - PIPE	GALV. STEEL
31	1	63DSB28102B	PV SYSTEM SCHEMATIC	VILLAGE LIGHT
30	1	69CSB28103B	PV SYSTEM WIRING DIAGRAM	VILLAGE LIGHT
29	6	802B11B003	WIRE TIE, BLACK	NYLON
28	8	¼" - 20	NUT-HEX	ST-ST
27	8	¼" NOM	WASHER - SPLIT LOCK	ST-ST
26	16	¼" NOM	WASHER-FLAT	ST-ST
25	8	¼"-20 X 3/4"	CAP SCREW HEX HD	ST-ST
24	52	3/8" NOM	WASHER-FLAT	ST-ST
23	32	P1008	SPRING NUT	GALV. STEEL
22	32	3/8"-16 X 1"	CAP SCREW-HEX HD	ST-ST
21	6	P1959EG	SQUARE NUT	GALV. STL.
20	4	¾"	FLEX CONNECTOR-SCREW IN	INSULATED
19	5 FT	¾"	CONDUIT-LIQUITITE	STEEL-FLEXIBLE
18	8	91578A202	ANCHOR BOLT (3/8"-16X3")	STEEL
17	2	2" PIPE	BOLT-'U',5/16"-18X3.2" LG	ZINC PLT. STEEL
16	1	P1121	CLAMP-POLE (UNISTRUT)	GALV. STEEL
15	4	P2345-EG	BRACKET-FOOT	GALV. STEEL
14	8	P1026-EG	BRACKET-ANGLE 90°	GALV. STEEL
13	1	27BSB28121B-001	CHANNEL-CLAMP	GALV. STEEL
12	4	27BSB28121B-002	RAIL-CONTROL STAND	GALV. STEEL
11	4	27BSB28121B-003	LEG-CONTROL STAND	GALV. STEEL
10	2	27BSB28151B	CHANNEL-MODULE SUPPORT	ANO. ALUM
9				
8				
7				
6	1	CTDB-20.23BG	POLE-VILLAGE LIGHT	GALV. STEEL
5	2	2000	BATTERY - 12 VDC	DELCO
4	1	16CSB28108B	BATTERY ENCLOSURE	
3	1	01ESB28104B	INSTRUMENT & CONTROL ASSY.	NEMA1
2	1	LSP-135-LT	LAMP-L.P.S. 12 VDC	R.E.C.
1	2	MSP43E40-B	SOLAR MODULE - 40 WATT	LAMINATED

BILL OF MATERIALS

UNLESS OTHERWISE SPECIFIED
TOLERANCES CENTIMETERS
XX ±0,5 CM
X ±1,0 CM
ANGULAR ±
√ RMS ALL MACHINED SURFACES
FEATURE CONTROL SYMBOLS PER ANSI Y14.5
BREAK ALL SHARP EDGES AND CORNERS REMOVE BURRS
UNDERLINED DIM NOT TO SCALE
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED

DRAWN BY Rue DATE 1.9.84
CHECKED BY DATE
ENGR APPROVAL DATE

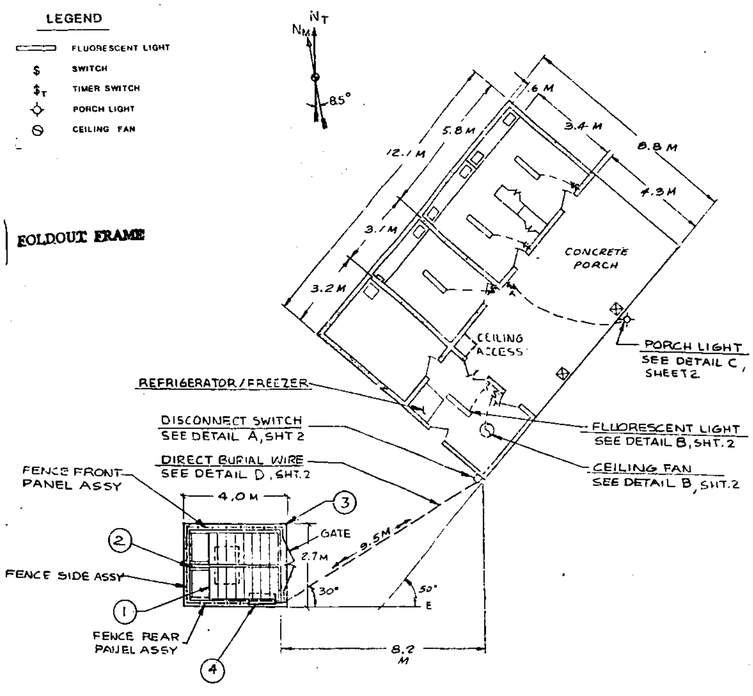
SOLAVOLT

TITLE
VILLAGE LIGHT SYSTEM
PV SYSTEM ASSEMBLY

SIZE D DRAWING NO 01DSB28101B
SCALE NOTED WEIGHT SHEET 2 OF 2

REVISIONS					
REV	ECO NO	CHANGE	DATE	BY	ENGR
0		INITIAL RELEASE	2-7-84	RC	WJK
A		CHANGED B.O.M.	3-21-84	JE	
B		CHANGED DETAIL 'B & C'	4-3-84	JE	
C		CHANGED P/N ITEM 35	4-5-84	JE	

FOLDOUT FRAME



FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MATL. SPEC.
21	1	1-1/2"	CLAMP CONDUIT	GALV. STEEL
20	100	MS-175	CABLE STAPLE	METAL
19	1	1-1/2"	FITTING-TYPE 'LB', PVC	CARLON
18	1	(1 1/2") RX150	HUB - BOLT-ON	CROUSE-HINDS
17	1 PT	921-010	CEMENT-FUSE ON TYPE	GRAY
16	1	1-1/2"	LOCKNUT - CONDUIT	GALV. STEEL
15	1	1-1/2"	TERMINAL ADAPTOR	PVC
14	1	1-1/2"	ROMEX CONNECTOR	GALV. STEEL
13	10'	1-1/2"	CONDUIT-SCH. 40	PVC
12	1	1-1/2"	COUPLING-FEM. S.XT.	PVC
11	1	1-1/2"	COUPLING-S.XS	PVC
10	1	1-1/2" X 90°	ELBOW-CONDUIT	PVC
9	1	SSWT0269	DISCONNECT SWITCH-60A	CROUSE-HINDS
8	24	MSB154	BATTERY- DHS-1	EXIDE
7	1	16DSB28109B	BATTERY ENCLOSURE	(BELOW ARRAY)
6	1	63DSB28083B	PV SYSTEM SCHEMATIC	DISPENSARY
5	1	69CSB28053B	PV SYSTEM WIRING DIAGRAM	DISPENSARY
4	1	01CSB28094B	PV SYS INSTRUMENT AND CONTROLS ASSY	
3	1	79CSB28056B	CONCRETE PAD - PV SYSTEM ARRAY	
2	1	01DSB28025B	PV SYSTEM ARRAY ASSY	
1	16	MSP43E40	SOLAR MODULE 40W	LAMINATED

BILL OF MATERIALS

NEXT ASSY: 79CSB28051B

SOLAVOLT INTERNATIONAL

TITLE: SCLOSSOVILLE DISPENSARY SYSTEM PV SYSTEM SITE PLAN

DRAWN BY		DATE	11-7-83
CHECKED BY		DATE	
ENGR. APPROVAL		DATE	

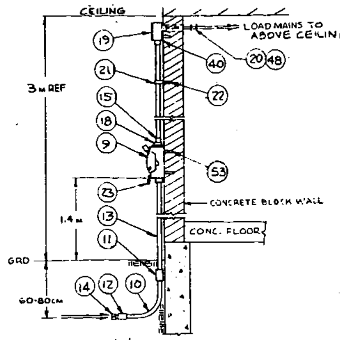
SIZE: C

DRAWING NO. 79CS928052B

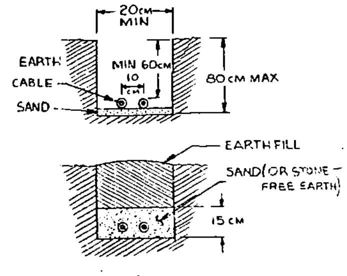
SCALE: 1/8"=1'-0"

SHEET 1 OF 2

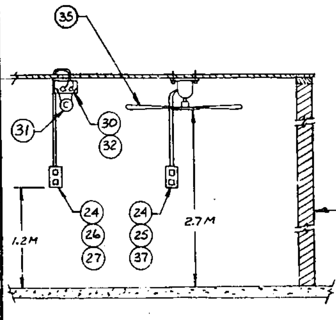
FOLDOUT FRAME



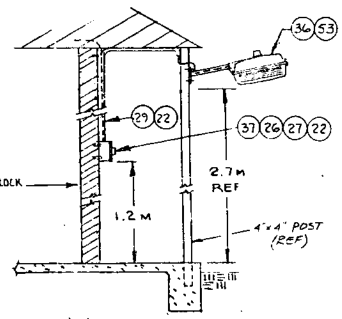
DETAIL 'A'-DISCONNECT SWITCH. INSTALLATION ASSEMBLY



DETAIL 'D'-DIRECT BURIAL



DETAIL 'B'- CEILING FAN & LIGHT



DETAIL 'C'-PORCH LIGHT

FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MATL. SPEC.
57	1	LTR 75	CONNECTOR-COMB. FLEX.	3/4"
56	1	SL-5	LOCKNUT-SEALING	1-1/5"
55	1	SL-4	LOCKNUT-SEALING	1-1/4"
54	1	SL-2	LOCKNUT-SEALING	3/4"
53	8	1/4" x 1-1/2"	WALL ANCHOR - NAILIN	
52	10'	1-1/4"	CONDUIT LIQUTITE	FLEXIBLE
51				
50				
49				
48	100	B02811B003	WIRE TIE-BLACK	NYLON 8"
47	1	738	CONNECTOR- 90°	3/4" FLEX
46				
45				
44	15'	3/4"	CONDUIT-LIQUITITE	FLEXIBLE
43	1	3/4"	ROMEX CONNECTOR	GALV. STEEL
42	2	740	90° CONNECTOR 1-1/4"	GALV. STEEL
41	1	RX-150	HUB-BOLTON	CROUSE-HINDS
40	1	SSM0285	SEALANT	SILICONE
39	50	#10 X 1"	SCREW-PHD TYPE 'A'	ZINC PLT. STEEL
38				
37	2	SSWT0276	SWITCH-TIMER	12 VDC
36	1	SSL0275	LPS LAMP ASSY.	18 WATT
35	1	SSMA0295	FAN-CEILING	12 VDC
34	1	SSF0273	REFRIGERATOR/FREEZER	12 VDC
33	25	704	STRAP	WIRE MOLD
32	25	30-076	WIRE NUT-RED	IDEAL
31	4	SSL0258	LAMP GUARD	40 WATT
30	4	MSC106	FLUORESCENT LIGHT	40 WATT
29	100'	TYPE	WIRE MOLD-RACEWAY	1-9/16" X 3/4"
28				
27	4	97-071	COVER PLATE SGL. SW.	ST-ST
26	4	SSMA0282-1	BOX-SWITCH, SGL.	WIRE MOLD
25	2	5744	BOX - SWITCH, DEEP	WIRE MOLD
24	4	SSWT0281	SWITCH-WALL	SPST
23	2	SSMA0283	PADDLOCK	STEEL
22	50	3/16 x 1"	WALL ANCHOR-NAILIN	RAWL

BILL OF MATERIALS

NEXT ASSY: 79CSB28051B

SOLAVOLT INTERNATIONAL

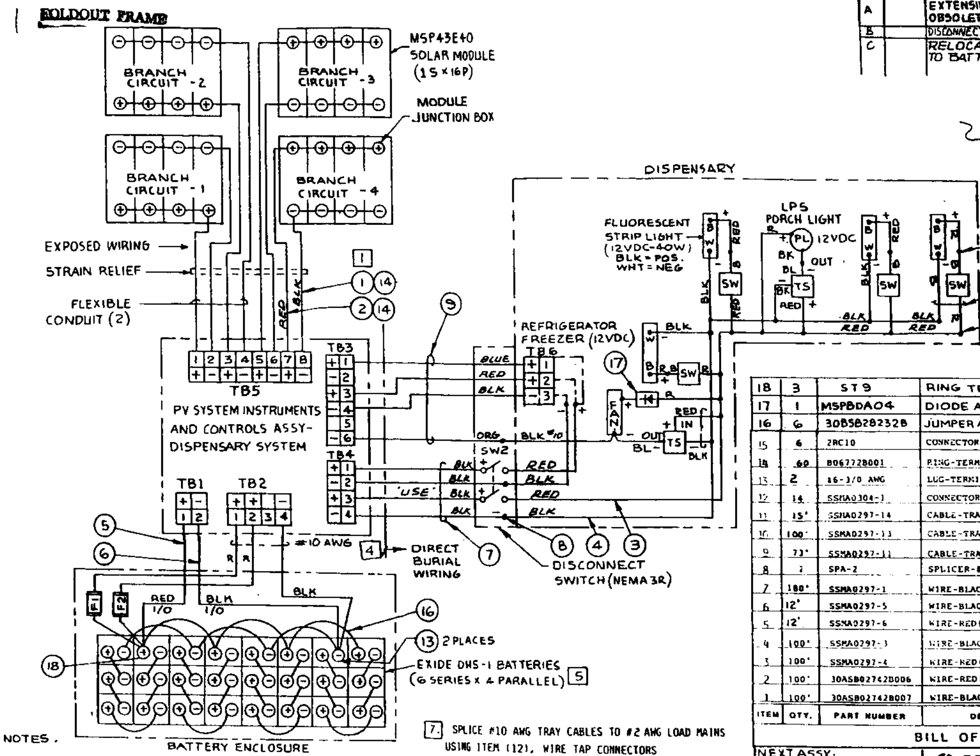
TITLE: BOLOBBOVILLE DISPENSARY SYSTEM PV SYSTEM SITE PLAN

DRAWN BY: Rac. DATE: 11-5-84
CHECKED BY: DATE:
ENGR APPROVAL: DATE:
SIZE: C DRAWING NO. 79CSB28052B
SHEET 2 OF 2

NOTES:
1. ITEMS IN BILL OF MAT'LS THAT DO NOT APPEAR IN DETAILS ARE USED FOR ARRAY WIRING HARDWARE.

REVISIONS					
REV.	ECO NO.	CHANGE	DATE	BY	ENGR.
O		INITIAL RELEASE	2-9-84	RC	WJK
A		EXTENSIVE CHANGES. SEE OBSOLETE ISSUE FOR DETAILS	32084	RC	WJK
B		DISCONNECTED TB6-2 FROM TB6-3	4-5-84	JE	
C		RELOCATED #10 WIRES TO BATTERIES (3 PLACES)	24OCT84	LML	RC

FOLDOUT FRAME



NOTES.

3. WIRING FROM PV ARRAY INSTRUMENTS ENCLOSURE TO PV BRANCH CIRCUITS, BATTERIES, AND LOADS TO BE WITHIN FLEXIBLE CONDUIT.

2. WIRE TERMINATIONS AT TB1 THRU TB6 ARE PRESSURE CONNECTIONS, (NOT REQUIRING CRIMP TERMINALS).

1. MODULE INTERCONNECT & BRANCH CIRCUIT WIRING TO BE #10 AWG XHHW RED-POS(+), BLACK-NEG.(-), CRIMP ON ITEM (14) AFTER WIRES ARE INSIDE THE MODULE J-BOX COVER.

7. SPLICE #10 AWG TRAY CABLES TO #2 AWG LOAD MAINS USING ITEM (12), WIRE TAP CONNECTORS

6. TRAY CABLE DROPS TO SWITCH BOXES TO BE WITHIN WIRE MOLD.

5. BATTERY INTERCONNECTS ARE SUPPLIED WITH BATTERIES, FOR SERIES CONNECTIONS.

4. SEE CONCRETE PAD DETAIL-DISPENSARY SYSTEM FOR CABLE ENTRANCE FITTING DETAILS.

ITEM	QTY.	PART NUMBER	DESCRIPTION	MATL. SPEC.
18	3	ST9	RING TERMINAL, #10-1/4"	
17	1	MSPBDA04	DIODE ASSY-BLOCKING	SOLARLOK
16	6	30BSB28232B	JUMPER ASSY-PARALLEL	#6AWG, BLACK
15	6	2RC10	CONNECTOR-BUTT	INSULATED, T&B
14	60	B067728001	RING-TERMINAL	INSULATED
13	2	#6-1/0 AWG	LUG-TERMINAL (BATTERY)	T&B, ALUM
12	14	SSMA0304-1	CONNECTOR-WIRE TAP (W/COVER)	ILSCO, ALUM
11	15'	SSMA0297-14	CABLE-TRAY (TIMER SWITCH)	600V, #10-3AWG
10	100'	SSMA0297-13	CABLE-TRAY (LIGHTS & FAN)	600V, #10-2AWG
9	73'	SSMA0297-11	CABLE-TRAY (REFRIGERATOR)	600V, #16-4AWG
8	2	SPA-2	SPLICER-#2-#14AWG	ILSCO, ALUM
7	180'	SSMA0297-1	WIRE-BLACK (DIRECT BURIAL)	USE, #2AWG
6	12'	SSMA0297-5	WIRE-BLACK (BATTERY-NEG.)	THHN, #1/0AWG
5	12'	SSMA0297-6	WIRE-RED (BATTERY-POS.)	THHN, #1/0AWG
4	100'	SSMA0297-3	WIRE-BLACK (INT. LOAD NEG.)	THHN, #2AWG
3	100'	SSMA0297-4	WIRE-RED (INT. LOAD POS.)	THHN, #2AWG
2	100'	30ASB02742B006	WIRE-RED (ARRAY POS.)	XHHW, #10AWG
1	100'	30ASB02742B007	WIRE-BLACK (ARRAY NEG.)	XHHW, #10AWG

BILL OF MATERIALS

NEXT ASSY. 79CSB28052B	SOLAVOLT INTERNATIONAL
	TITLE: BOLOSSOVILLE DISPENSARY SYSTEM PV SYSTEM WIRING DIAGRAM
DRAWN BY Russ C. DATE 1-30-84	SIZE C DRAWING NO. 69CSB28053B
CHECKED BY DATE	
ENGR. APPROVAL DATE	SHEET 1 OF 1

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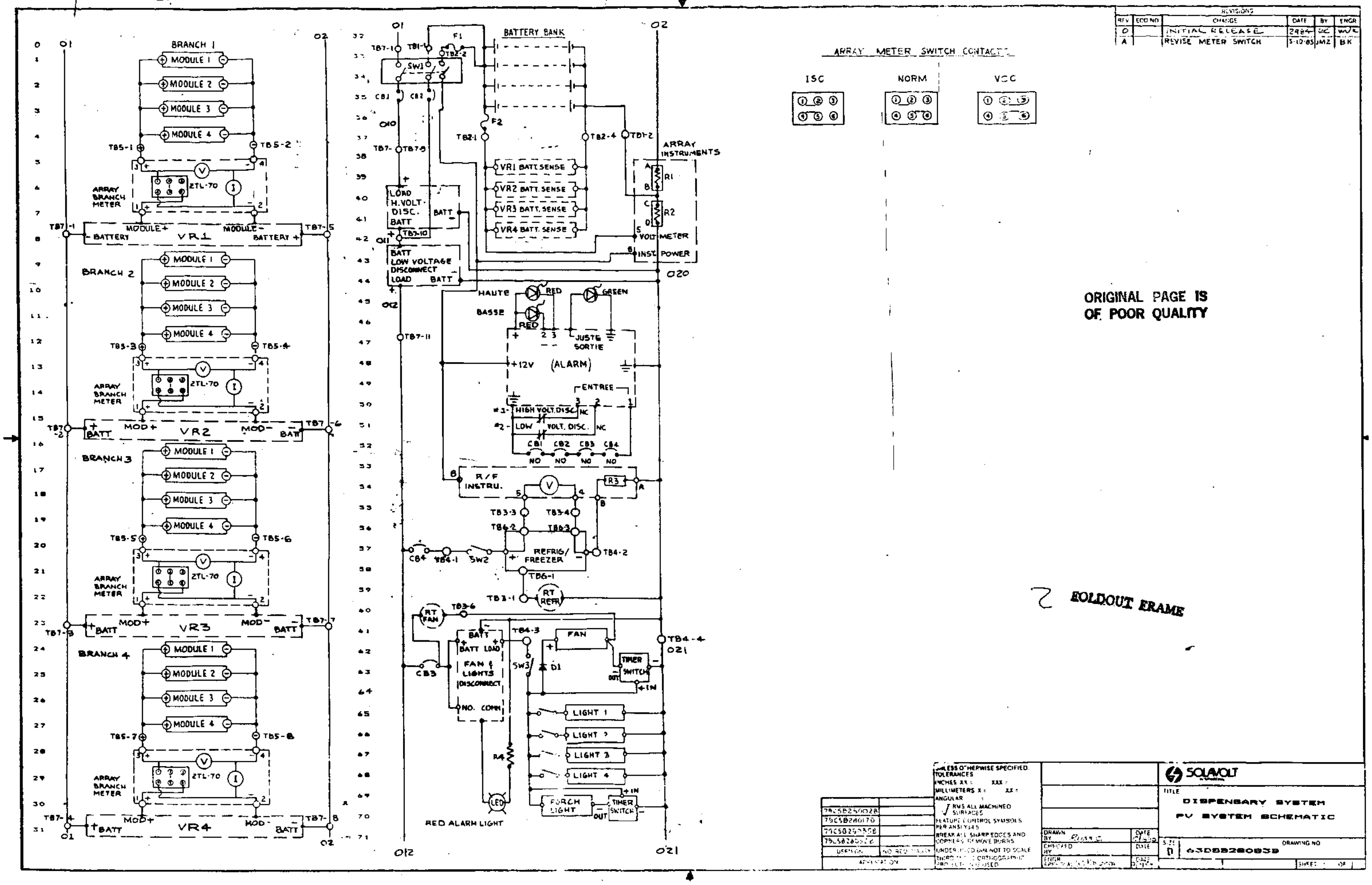
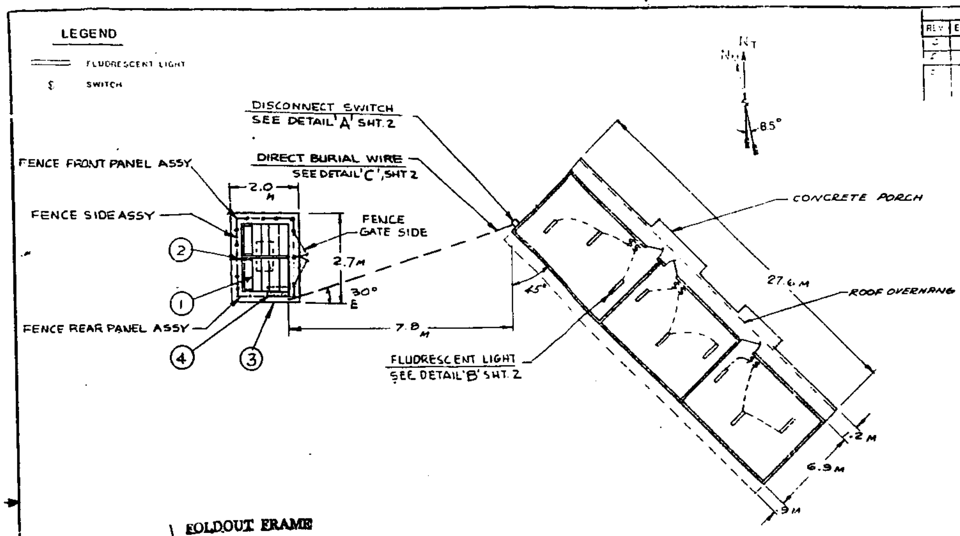
FOLDOUT FRAME



2 FOLDOUT FRAME



2 FOLDOUT FRAME

1 FOLDOUT FRAME

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L. SPEC.
9	—	—	CONTINUED ON SHEET 2	—
8	12	MSB 154	BATTERY, DHS-1	EXIDE
7	1	160SB26108B	BATTERY ENCLOSURE	(BELOW ARRAY)
6	1	63DSB28058B	PV SYSTEM SCHEMATIC	BOLOSSOVILLE
5	1	69CSB28059B	PV SYSTEM WIRING DIAGRAM	BOLOSSOVILLE
4	1	01CSB28063B	PV SYS INSTRUMENT AND CONTROLS ASSY	
3	1	79CSB28062B	CONCRETE PAD - PV SYSTEM ARRAY	
2	1	01CSB2613E B	PV SYSTEM ARRAY ASSY	10 MODULE
1	8	MSP43E40	SOLAR MODULE 40W	LAMINATED

BILL OF MATERIALS

NEXT ASSY: 79CSB28051B

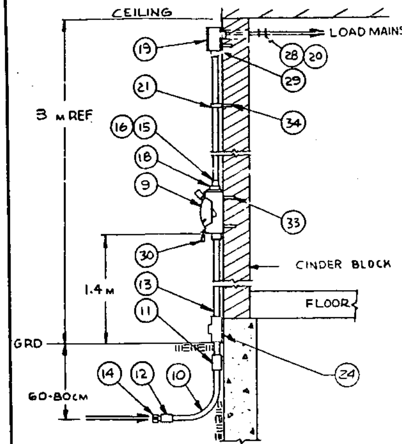
SOLAVOLT

TITLE: BOLOSSOVILLE SCHOOL SYSTEM PV SYSTEM SITE PLAN

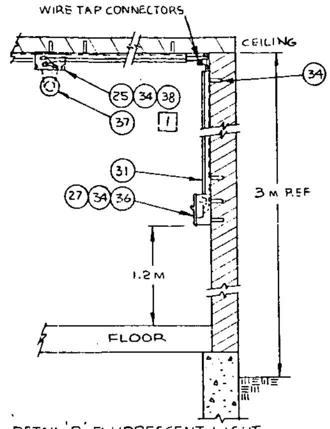
DRAWN BY | DATE
CHECKED BY | DATE
ENGR APPROVAL | DATE

SIZE C | DRAWING NO 79CSB28057D

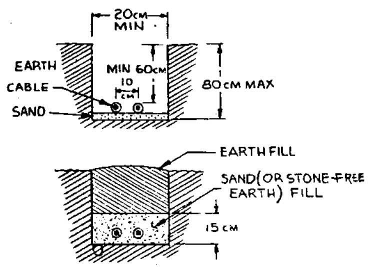
SCALE | SHEET 1 OF 2



DETAIL 'A'-DISCONNECT SWITCH.
INSTALLATION ASSEMBLY



DETAIL 'B'-FLUORESCENT LIGHT.
INSTALLATION ASSEMBLY



DETAIL 'C'-DIRECT BURIAL

ITEM	QTY.	PART NUMBER	DESCRIPTION	MAT'L.SPEC.
49	1	LTR75	CONNECTOR-COMB.FLEX.	3/4"
48	1	SL-5	LOCKNUT-SEALING	1-1/5"
47	1	SL-4	LOCKNUT-SEALING	1-1/4"
46	1	SL-2	LOCKNUT-SEALING	3/4"
45	1	3/4"	ROMEX CONNECTOR	GALV. STEEL
44				
43	1	738	CONNECTOR-90°	3/4" FLEX.
42	15'	3/4"	CONDUIT-LIQUITITE	FLEXIBLE
41				
40				
39	25	#10x1"	SCREW-PHD. TYPE 'A'	ZINC PLT STEEL
38	25	30-076	WIRE NUT-RED	IDEAL
37	9	SSL0258	LAMP GUARD	PLASTIC
36	3	97-072	SWITCH PLATE-DBL	ST-ST
35	50	704	STRAP	WIREMOLD
34	50	3/16" X 1"	WALL ANCHOR-NAILIN	RAWL
33	4	1/4 X 1-1/2"	WALL ANCHOR-NAILIN	RAWL
32	50'	3608T26	CHAIN-(OPTIONAL)SAFETY	GALV.STEEL
31	160'	TYPE 700	WIRE MOLD-RACEWAY	
30	2	SSMA0283	PADLOCK	
29	1	SSM0285	SEALANT	SILICON RUBBER
28	100	B02811B003	WIRE TIE-BLACK	NYLON 8"
27	3	SSMA0282-2	SWITCH BOX - DBL	WIREMOLD
26	6	SSWT0281	SWITCH-WALL	SPST
25	9	MSC106	FLUORESCENT LIGHT	40W
24	1	1-1/2"	FITTING - TYPE 'C'	PVC
23	2	740	CONNECTOR 90°	1-1/4" FLEX
22	10'	1-1/4"	CONDUIT LIQUITITE	FLEXIBLE
21	1	1-1/2"	CLAMP CONDUIT	GALV. STEEL
20	100	MS-175	CABLE STAPLE	METAL
19	1	1-1/2"	FITTING-TYPE 'LB', PVC	CARLON
18	1	(1-1/2")RX150	HUB - BOLT-ON, W/BOLTS	CROUSE-HINDS
17	1 PT	921-010	CEMENT-FUSE ON TYPE	GRAY
16	1	1-1/2"	LOCKNUT - CONDUIT	GALV. STEEL
15	2	1-1/2"	TERMINAL ADAPTOR	PVC
14	1	1-1/2"	ROMEX CONNECTOR	GALV. STEEL
13	10'	1-1/2"	CONDUIT-SCH. 40	PVC
12	1	1-1/2"	COUPLING-FEM. S.XT.	PVC
11	1	1-1/2"	COUPLING-S.XS	PVC
10	1	1-1/2" X 90°	ELBOW-CONDUIT	PVC
9	1	SSWT0269	DISCONNECT SWITCH-60A	CROUSE-HINDS

BILL OF MATERIALS

NEXT ASSY: 79CSB28051B

SOLAVOLT 2 FOLDOUT FRAME

TITLE: BOLOSSOVILLE SCHOOL SYSTEM PV SYSTEM SITE PLAN

DRAWN BY ___ DATE ___
CHECKED BY ___ DATE ___
ENGR APPROVAL ___ DATE ___

SIZE C DRAWING NO. 79CSB28057B SHEET 2 OF 2

FOLDOUT FRAME

2. ITEMS IN BILL OF MAT'LS THAT DO NOT APPEAR IN DETAILS ARE USED FOR ARRAY WIRING HARDWARE.

1. SAFETY CHAIN, ITEM 32, MAY BE USED TO HANG LIGHTS FROM CEILING, A MINIMUM OF 2.4 M FROM THE FLOOR, USING SCREWS - ITEM 39.

NOTES:

A P P E N D I X B

MANUFACTURER'S LITERATURE

SOLAVOLT MSP43E40	MODULE
EXIDE DHS-1	BATTERY
DELCO D-2000	BATTERY
SCI METER BOX	
SOLAVOLT MSR12S10	VOLTAGE REGULATOR
SCI BATTERY SAVER	
REC SPECIALTY FLUORESCENT LIGHTS	
REC SPECIALTY LPS LIGHTS	
SUN-AMP TIMER SWITCH	
MARVEL 4RTD REFRIGERATOR	
WEKSLER TEMPERATURE RECORDER	
JACUZZI SOLARFLOW PUMPS	
SALORA TV	

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P O BOX 2934 ● PHOENIX, ARIZONA 85062

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MSP13E10
MSP23E20
MSP43E40

10-WATT, 20-WATT AND 40-WATT SOLAR MODULES

Solavolt photovoltaic modules utilize advanced technology 25 mm × 100 mm (1 in. × 4 in.), 50 mm × 100 mm (2 in. × 4 in.), or 100 mm × 100 mm (4 in. × 4 in.) silicon solar cells. The rectangular cell provides for high cell packing density which yields maximum power with minimum module area. Balance of systems costs (e.g., structures, wiring, mountings and ground area) are also reduced by increasing cell packing density.

A 33 series cell design is used to make optimum use of silicon area in battery charging applications while decreasing the potential for overvoltage conditions to occur at the battery terminals. Computer analysis and extensive field testing prove that the 33 cell configuration provides ample charging voltage in all climates. All material and construction techniques have a proven history of reliability and conform to all applicable Department of Energy/Jet Propulsion Lab test specifications.

FEATURES

- High Packing Density
- High Reliability Due to Redundant Interconnects
- Across-the-Cell Contacts Eliminate Potential Power Loss Due to Cracked Cells
- 33 Cells in Series
- 10-, 20- and 40-Watt Peak Power
- Maintenance-Free Construction, Tempered Glass Superstrate, Anodized Aluminum Frame
- Low Temperature NOCT = 45°C
- Metric Dimensions
  MSP13E10 — 358.1 mm × 377.8 mm
  MSP23E20 — 358.1 mm × 637.5 mm
  MSP43E40 — 358.1 mm × 1216.6 mm
- Designed to Exceed JPL Block 4 Requirements, JPL Spec 5101-16 Rev A

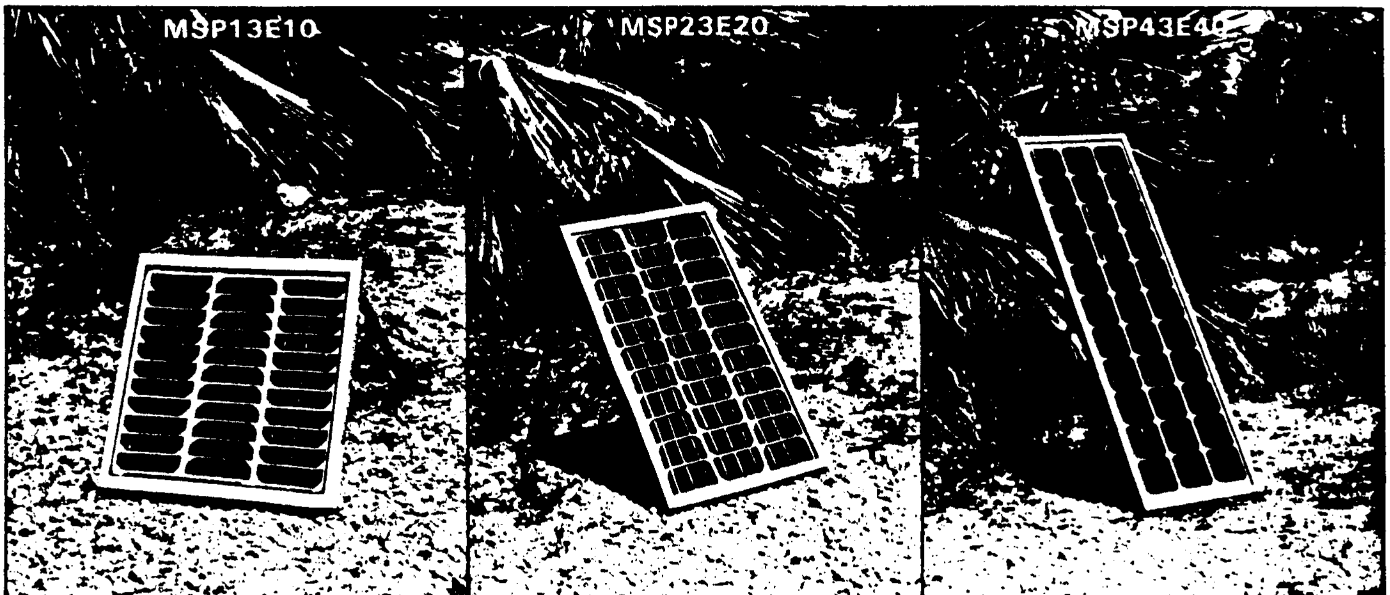
APPLICATIONS

Village Power
Remote Communications
Offshore Equipment
Cathodic Protection
Forestry Equipment
Instrumentation
Water Pumping
Microwave Relays
Navigational Aids
Portable Equipment
Emergency Phones
Cabins
Remote Medical Refrigerators

SYSTEMS ENGINEERING

In addition to photovoltaic modules, we supply other system components, including voltage regulators, steel support structures and wiring, batteries, and end use hardware such as water pumps, refrigerators and lighting systems.

Our staff of application engineers is available to assist you in system definition and system sizing.



Solavolt International is a partnership of Motorola Solar Energy, Inc. (a subsidiary of Motorola, Inc.) and SES, Incorporated (a subsidiary of Shell Oil Company)

Photos courtesy of the Phoenix Zoo

DS2210R2

MSP13E10
MSP23E20
MSP43E40

ELECTRICAL

MSP13E10

CONDITIONS Air Mass 1.5	I_{SC} Typ	I_M Min	@ V_{NO}	V_{OC} Typ	P_M Min	P_M Typ
T_C = 28°C, 100 mW/cm^2	0.65	0.55	15.8	19.5	9.0	10
T_A = 20°C, T_C = 50°C, 100 mW/cm^2	0.65	0.55	14.3	17.9	8.1	9.1

Temperature Coefficients:

TC V_{OC} = -0.0022 V/C/Cell (Series)
TC V_{NO} = -0.00213 V/C/Cell (Series)
TC I_{SC} = 0.00008 A/C/Cell (Parallel)
TC I_M = 0.00008 A/C/Cell (Parallel)

MSP23E20

CONDITIONS Air Mass 1.5	I_{SC} Typ	I_M Min	@ V_{NO}	V_{OC} Typ	P_M Min	P_M Typ
T_C = 28°C, 100 mW/cm^2	1.3	1.1	15.8	19.5	18	20
T_A = 20°C, T_C = 50°C, 100 mW/cm^2	1.3	1.1	14.3	17.9	16.3	18.1

Temperature Coefficients:

TC V_{OC} = -0.0022 V/C/Cell (Series)
TC V_{NO} = -0.00213 V/C/Cell (Series)
TC I_{SC} = 0.00036 A/C/Cell (Parallel)
TC I_M = 0.00036 A/C/Cell (Parallel)

MSP43E40

CONDITIONS Air Mass 1.5	I_{SC} Typ	I_M Min	@ V_{NO}	V_{OC} Typ	P_M Min	P_M Typ
T_C = 28°C, 100 mW/cm^2	2.6	2.3	15.8	19.5	36.5	40
T_A = 20°C, T_C = 50°C, 100 mW/cm^2	2.6	2.3	14.3	17.9	33.3	36.6
T_A = 20°C, T_C = 45°C, 80 mW/cm^2	2.1	1.9	14.4	17.9	26.9	29.5
T_A = 40°C, T_C = 65°C, 80 mW/cm^2	2.1	1.9	13.0	16.4	24.6	27.1

Temperature Coefficients:

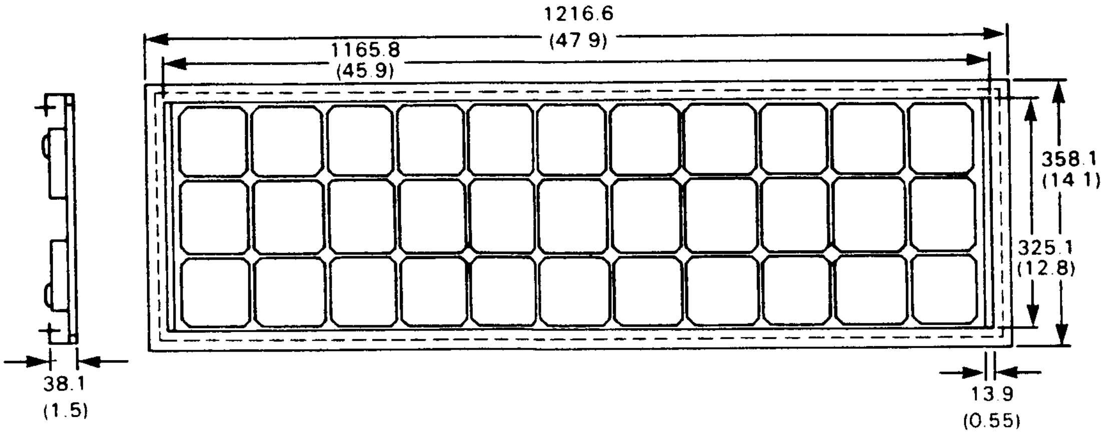
TC V_{OC} = -0.0022 V/C/Cell (Series)
TC V_{NO} = -0.00213 V/C/Cell (Series)
TC I_{SC} = 0.00159 A/C/Cell (Parallel)
TC I_M = 0.00159 A/C/Cell (Parallel)

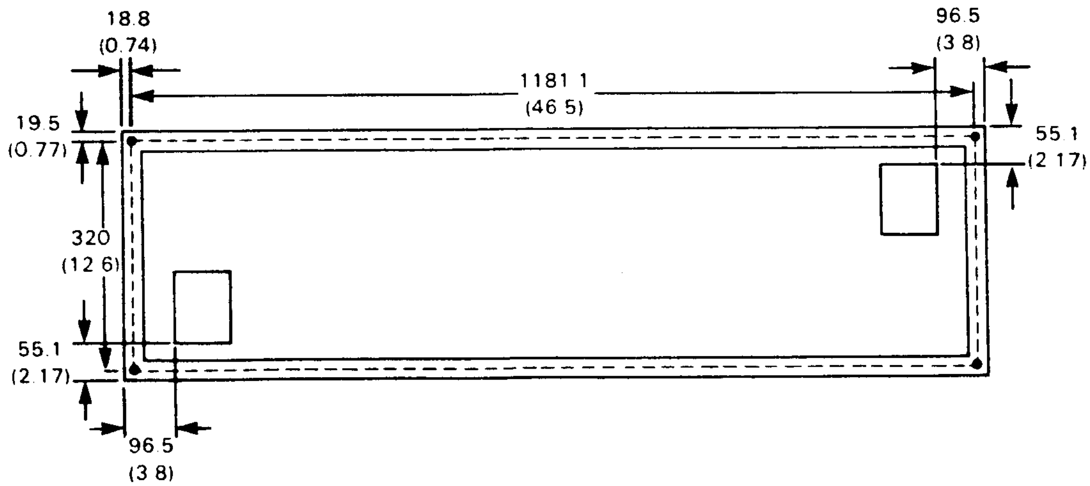
I_{SC} = Short Circuit Current, Adc
I_M = Current, Adc, Measured at V_{NO}
V_{NO} = Nominal Operating Voltage, Vdc, is the Reference Voltage Level at which the Modules are Designed to Provide Maximum Power Output at Specified Operating Conditions. (Approximately equal to V_M.)
V_{OC} = Open Circuit Voltage, Vdc
P_M = Maximum Power, Watts
T_A = Ambient Temperature, °C
T_C = Cell Temperature, °C
NOCT = Normal Operating Cell Temperature

Voltage Changes: V_{OC} decrease 2% when irradiance decreases from 100 mW/cm^2 to 80 mW/cm^2
V_{NO} does not change appreciably with changes in irradiation level.

MECHANICAL

MSP43E40





Weight (Nominal): 6.1 kg (13.5 lb)   Dimensions in $\frac{\text{millimeters}}{\text{inches}}$

Shock: 0.4 m(15 inch) drop per MIL-STD-810B, Method 516, Procedure V   Snow Loading: 290 kg/m^2 (60 lb/ft^2) maximum

Vibration: per MIL-STD-810B, Method 514, Procedure X

SOLAVOLT INTERNATIONAL

MSP13E10
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MSP43E40

CONSTRUCTION

Cover Glass: 0.125 in. tempered Solatex®, Low Iron Content Glass
Encapsulant: Polyvinyl Butyral
Cells: 33 in Series
Back: Aluminized Tedlar® (Polyvinyl Fluoride, and Aluminum Foil)
Edge Sealant: Polymeric System
Frame: Anodized Aluminum Alloy
Interconnect (Cell): Three Continuously Bonded-Copper Ribbons Across Top and Bottom of Cells
Connection (External): Weather Resistant Junction Box with Internal Electrical Connection Points

ELECTRICAL INSULATION TO FRAME

1600 Vdc minimum

OPERATIONAL CONDITIONS

Temperature (Ambient): -40°C to +60°C (-40°CF to +140°F)
Nominal Operating Cell Temperature: 45°C at T_A = 20°C, 80 mW/cm^2, Wind at 1 m/s, Module Tilted
Wind: Constant Velocity, 160 km/hr (100 mph) maximum
Gust Velocity, 200 km/hr (125 mph) maximum

STORAGE TEMPERATURE

-40°C to +60°C (-40°F to +140°F)

FIGURE 1 — SINGLE 1-in. × 4-in. CELL CHARACTERISTIC

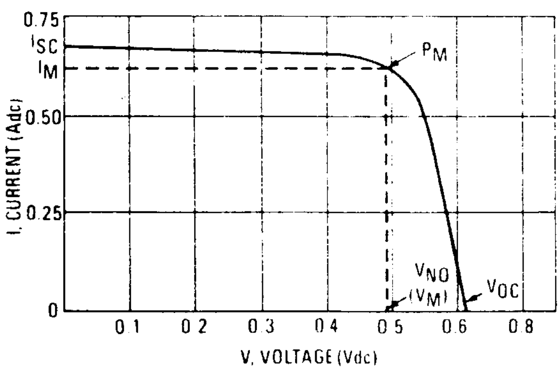


FIGURE 2 — SINGLE 2-in. × 4-in. CELL CHARACTERISTIC

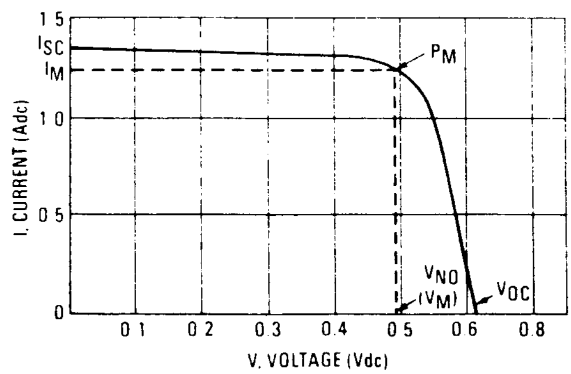


FIGURE 3 — SINGLE 4-in. × 4-in. CELL CHARACTERISTIC

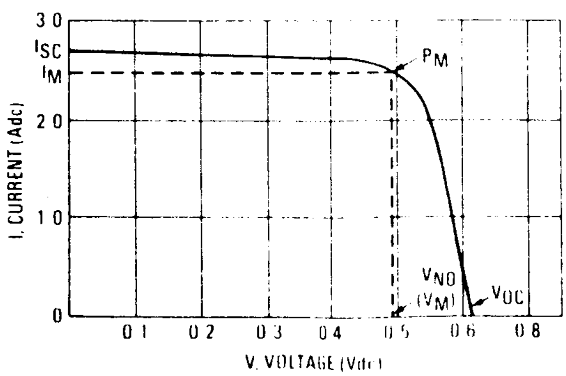


FIGURE 4 — MSP13E10 MODULE CHARACTERISTICS

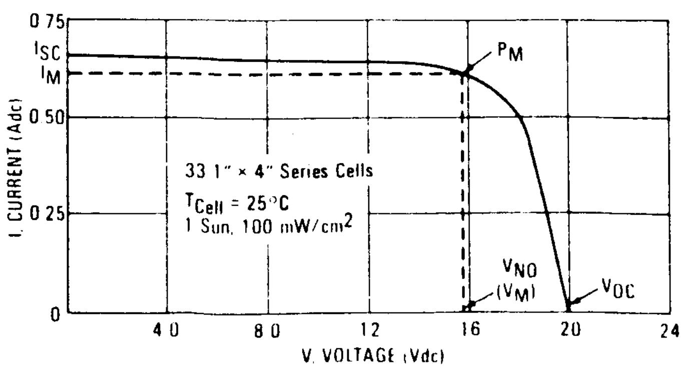


FIGURE 5 — MSP23E20 MODULE CHARACTERISTICS

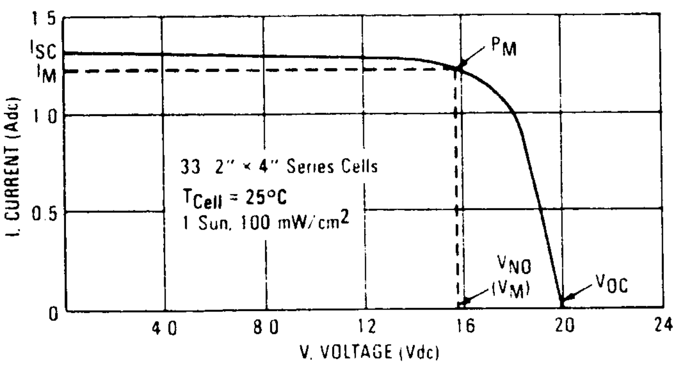


FIGURE 6 — MSP43E40 MODULE CHARACTERISTICS

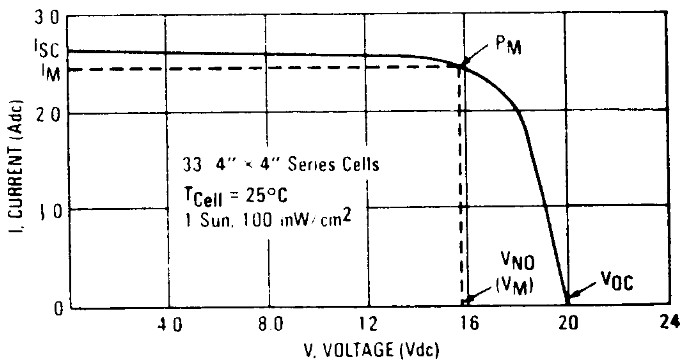


FIGURE 7 — MSP13E10 MODULE CHARACTERISTIC versus SUNLIGHT INTENSITY

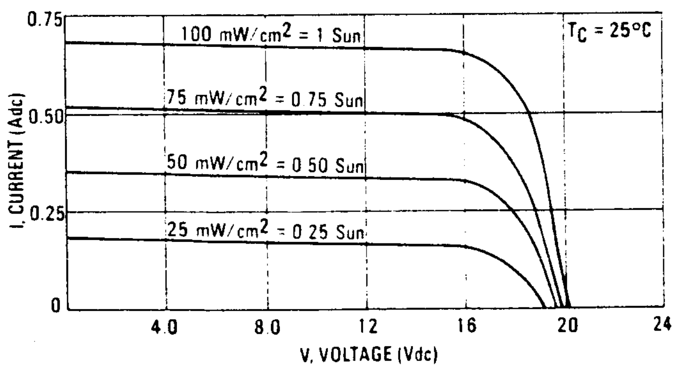


FIGURE 8 — MSP23E20 MODULE CHARACTERISTIC versus SUNLIGHT INTENSITY

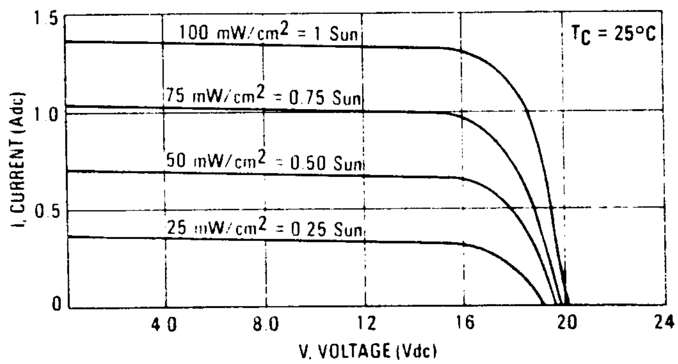


FIGURE 9 — MSP43E40 MODULE CHARACTERISTIC versus SUNLIGHT INTENSITY

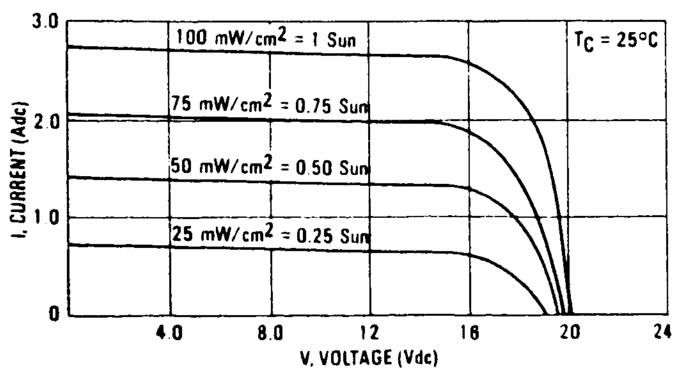
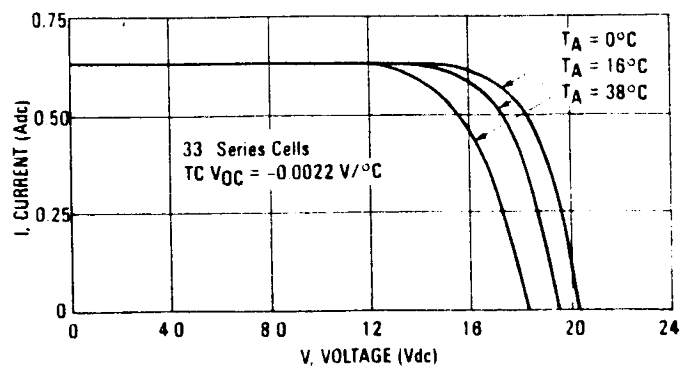


FIGURE 10 — MSP13E10 MODULE CHARACTERISTIC versus TEMPERATURE



SOLAVOLT INTERNATIONAL

MSP13E10
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FIGURE 11 — MSP23E20 MODULE CHARACTERISTIC versus TEMPERATURE

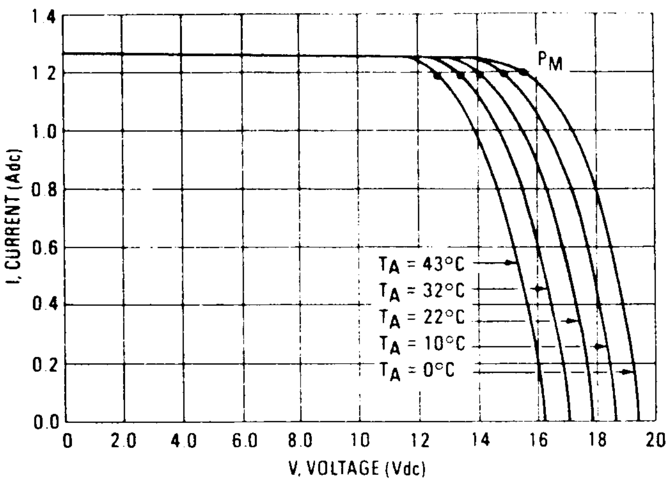
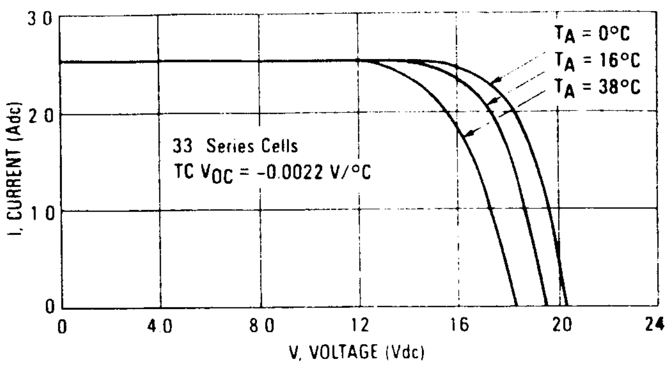


FIGURE 12 — MSP43E40 MODULE CHARACTERISTIC versus TEMPERATURE



ADVANCED FEATURES OF SOLAVOLT SOLAR CELLS

The surface of each silicon solar cell (Figure 13) is textured, forming a dense population of pyramids as shown in the scanning electron microscope view (Figure 14). The reflected part of a vertical light ray impinging on a textured surface strikes the surface of an adjacent pyramid where a secondary absorption takes place. With a suitable anti-reflection coating, such as the silicon nitride utilized in Solavolt solar cells, the total energy transmitted into the active area of the cell is more than 99% of that of the incident solar irradiation. In addition to greatly reducing reflection, the textured surface diffracts more incident light so that it travels through the solar cell at appreciable angles from the normal, thereby producing more photo-generation near the collecting N-P junction (which is close to the upper surface) and increasing path lengths for the longer wavelength portions of the solar spectrum, both of which enhance efficiency.

FIGURE 13 — 100 mm × 100 mm PHOTOVOLTAIC CELL

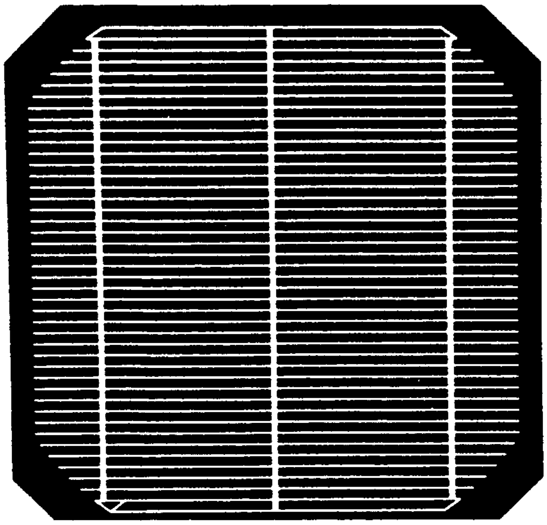
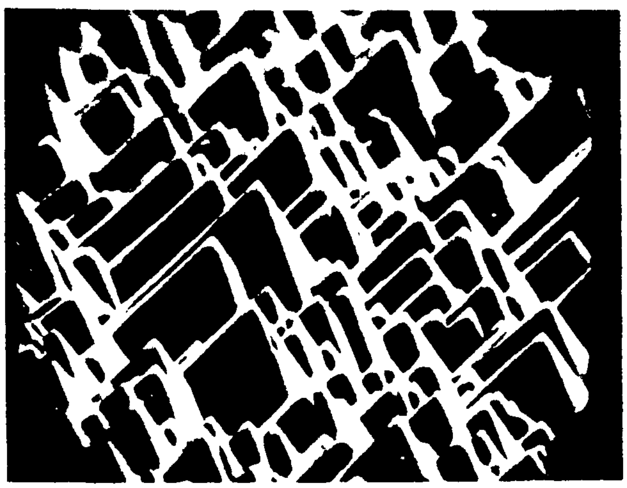
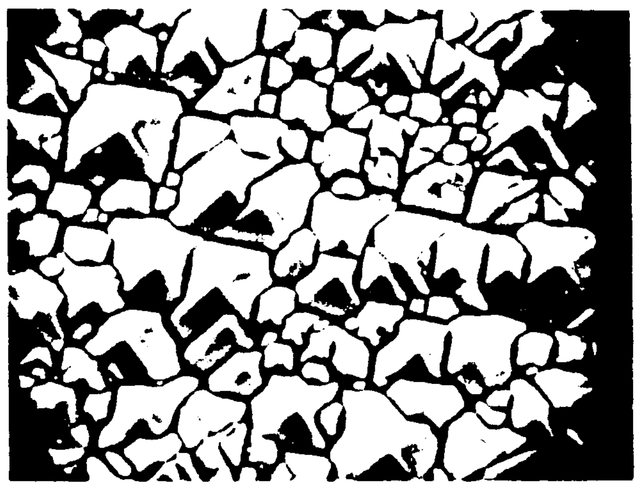


FIGURE 14 — SCANNING ELECTRON MICROSCOPE PHOTO OF TEXTURED CELL SURFACE



(a) 80° View (2000X)



(b) Normal View (2000X)

SYSTEM SIZING

Solavolt Solar Operations has a staff of applications engineers experienced in the design of photovoltaic solar systems. With the aid of a computer sizing program, systems can be tailored to any site location and load condition. The computer program will determine optimum array tilt angle, the number of modules in series and parallel required, amp-hour battery capacity needed, and system performance.

The following information is required from the user.

1. Application, e.g., Communications equipment, water pump, cathodic protection.
2. Location (city, state, country, and/or latitude and longitude, and site elevation).
3. System voltage and/or battery voltage.
4. Current drain average (amps) for a 24-hour period.
5. Temperature, minimum and maximum, if known.
6. Nature of site:
   a. Attended site
   b. Unattended, accessible site
   c. Unattended, inaccessible site
   d. Unattended, inaccessible site of a critical nature.
7. Special or unusual conditions.

The following example for a remote repeater application will demonstrate the Solavolt methodology for system sizing.

Given data:

1. Communications Equipment
2. Location: Phoenix, Arizona (33.26 N. Latitude, 112.01 W. Longitude, elevation = 1200')
3. System Voltage: 12 Volts nominal (battery)
4. Daily load: 1 amp average for 24 hours (24 AH/day)
5. -1.0°C (30°F) minimum, 43°C (110°F) maximum.
6. Unattended, inaccessible site.

These data (location, voltage, load) along with weather data, result in a computer printout (Figure 15) which gives the optimum system configuration and its projected performance.

The calculations to arrive at this point are based on the following techniques. Monthly averages of solar irradiation at the given location are calculated for arrays mounted at a range of different angles. For each of these angles, the lowest cost combination of array size and battery capacity needed to supply the load all year is calculated. If the array size is increased slightly above the minimum, the additional module cost is sometimes more than offset by a savings on batteries, thus reducing the total system cost. Further increases in array size will eventually result in higher total cost. Hence the need for computer optimization to find the best combination of array size, seasonal battery storage capacity and array mounting angle. The seasonal battery storage capacity is based on the worst-case accumulated deficiency that the batteries would have to handle over any 13-month period.

The additional no-sun days battery capacity is based on the load requirements and the specified number of successive no-sun days. The life of lead-acid batteries is substantially increased if deep discharge is avoided. It is recommended that the battery charge condition not drop below 20% of full charge for pure lead plates, or 50% for lead-calcium plates.

The optimum system for this particular application, as shown in Figure 15, consists of a south-facing array, tilted at 43 degrees from the horizontal, using 2 MSP43E40 solar modules in parallel.

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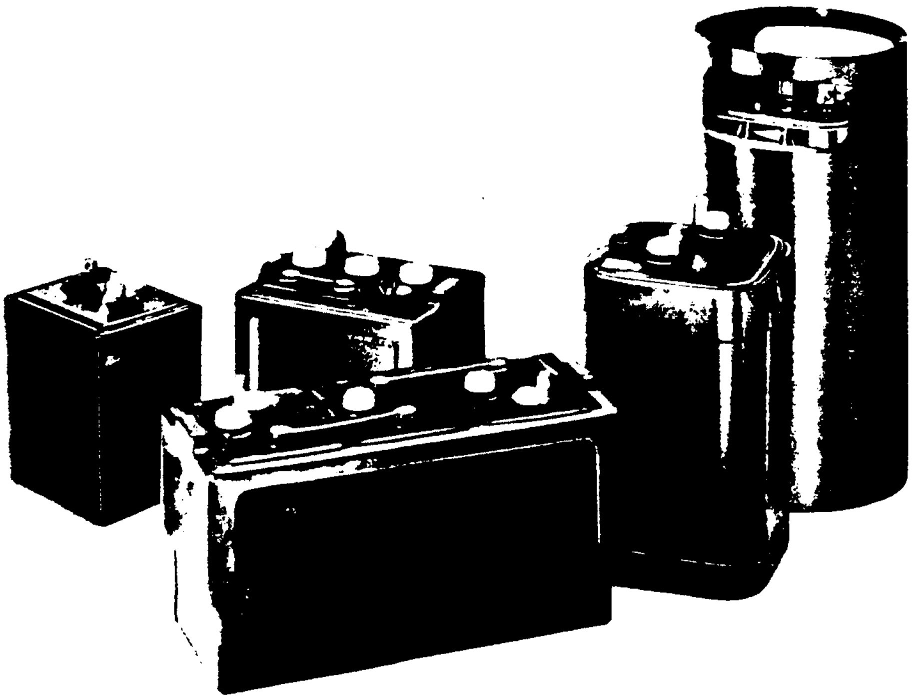
EXIDE®

Charge Retaining Batteries for Shallow Cycle Solar

Features

- ☐ PURE LEAD GRIDS FOR LONG FLOAT SERVICE
- ☐ EXTRA THICK POSITIVE AND NEGATIVE PLATES
- ☐ HIGH SPECIFIC GRAVITY - 1.300 - FOR FREEZING PROTECTION
- ☐ LOW WATER LOSS - UP TO 2 YEARS BETWEEN FILLING
- ☐ HEAVY CONSTRUCTION - FUNCTIONS AT TEMPERATURE EXTREMES
- ☐ LONG LIFE - UP TO 5 YEARS IN SHALLOW CYCLE SERVICE



Applications — Shallow Cycle (3 Days - 21 Days)

- ☐ NAVIGATION BUOYS AND MARKERS
- ☐ SHALLOW CYCLE PHOTOVOLTAIC
- ☐ SHALLOW CYCLE WIND
- ☐ HIGH AND LOW TEMPERATURE EXTREMES
- ☐ UNREGULATED CHARGING TOLERATED
- ☐ 100AH-500AH SIZES - 2 VOLT AND 6 VOLT UNITS
- ☐ AVAILABLE • CHARGED AND WET

SPECIFICATIONS

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Cell/Unit Dimensions — Weights:

TYPE	NOM. A.H. CAP.	CAT. NO.	DESCRIPTION	OVERALL DIMENSIONS LENGTH in.	mm.	WIDTH in.	mm.	HEIGHT in.	mm.	WEIGHTS—VOLUMES UN-PACKED lbs.	kg.	DOMESTIC PACKED lbs.	kg.	ELECTROLYTE ONLY 1.300 SP. GR. lbs.	kg.	gal.	l
3-DD-3 3-DD-3	100	07742 04825	"L" Terminals Wing Nuts	8.5	216	6.8	172	9.6	244	40	18	44	20	10	4.7	1.0	3.6
DD-5	200	04193	"L" Terminals	7.1	179	5.5	139	9.5	241	26	12	29	13	7	3.0	.6	2.2
3-DD-5	200	04118	"L" Terminals	16.1	409	7.1	179	9.5	241	76	34	84	38	20	8.9	1.8	6.9
DH-5	500	05476	"L" Terminals	7.6	192	8.3	211	14.0	356	58	26	64	29	16	7.4	1.5	5.7
DH-5	500	01388	"L" Terminals Steel Can with Handles	8.3	211	9.0	229	18.3	466	68	31	75	34	16	7.4	1.5	5.7
DHB-5	500	06578	"L" Terminals, Marine Spill Proof Vent	7.6	192	8.3	211	16.4	418	58	26	64	29	15	7.0	1.4	5.3
DHB-5	500	05757	"L" Terminals Round Steel Can Marine Spill Proof Vent	9.25"" Diam. 235 mm Diam.				16.4	418	62	28	69	31	15	7.0	1.4	5.3

Plates:

TYPE	NOM. A.H. CAP.	HEIGHT in	mm	WIDTH in	mm	THICKNESS POSITIVE in	mm	NEGATIVE in	mm	OUTSIDE NEGATIVE in	mm
DD-3	100	5.4	133	5.6	143	.6	16	.3	8	—	—
DD-5	200	5.4	133	5.6	143	.6	16	.6	16	.3	8
DH-5	500	8.1	209	6.0	152	.9	24	.9	24	.4	10

	3-DD-3 in	mm	DD-5 in	mm	3-DD-5 in	mm	DH-5 in	mm	DHB-5 in	mm
ELECTROLYTE OVER PLATES	1.8	44	.8	20	.8	20	1.8	44	1.8	44
SEDIMENT SPACE	.8	20	.7	17	.7	17	.7	17	.7	17
VENT TYPE	SCREW PLUG—SPILL PROOF OPTIONAL								MARINE SPILL PROOF	
CONTAINER MATERIAL	HARD RUBBER									
COVER MATERIAL	HARD RUBBER									
SEPARATOR MATERIAL	MICROPOROUS HARD RUBBER									
PLATE SUSPENSION	BOTTOM SUPPORTED									
SPECIFIC GRAVITY	1.300									
BOLT CONNECTORS —"L" TYPE	¼" - 20 × 1"									
—WING NUT	¼" - 20									
INTER UNIT CONNECTORS	#8 AWG JUMPERS - 14" (360mm) WITH BOLT ON LUGS									

AVERAGE CELL PERFORMANCE DATA

Discharge Rates in Ampere Hours and Amperes
1.300 Specific Gravity Electrolyte at 77°F (25°C)

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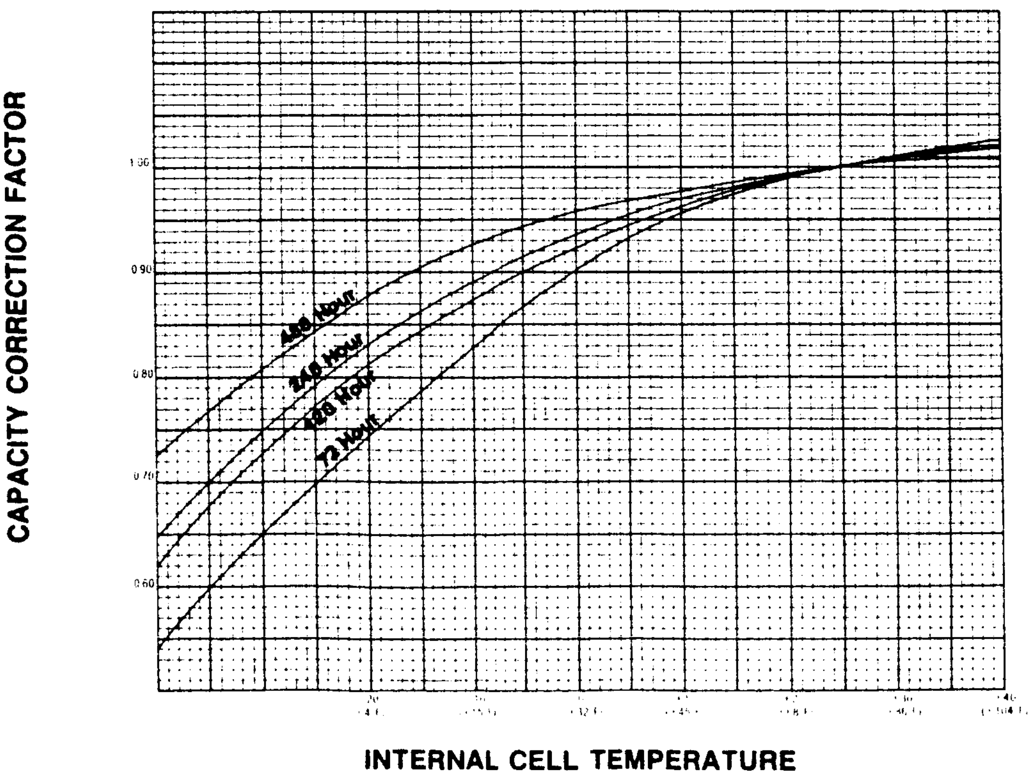
To 1.90 Volts Per Cell

TYPE	VOLTAGE PER UNIT	500 HR A.H. CAP.	20 DAY 480 HR A.H.	20 DAY 480 HR AMPS	10 DAY 240 HR A.H.	10 DAY 240 HR AMPS	5 DAY 120 HR A.H.	5 DAY 120 HR AMPS	3 DAY 72 HR A.H.	3 DAY 72 HR AMPS	32°F 0°C 500 HR A.H.
3-DD-3	6	100	100	.21	97	.40	95	.79	92	1.28	95
DD-5 3-DD-5	2 6	200	200	.42	195	.81	190	1.58	184	2.56	190
DH-5 DHB-5	2 2	500	500	1.04	490	2.04	480	4.00	460	6.39	475

FINISHING CHARGE VOLTAGES: 2.30 VPC FOR MINIMUM WATER LOSS
2.50 VPC FOR MAXIMUM RECHARGE

SELF DISCHARGE RATES: 1% PER MONTH AT 77°F (25°C)
6% PER MONTH AT 132°F (55°C)

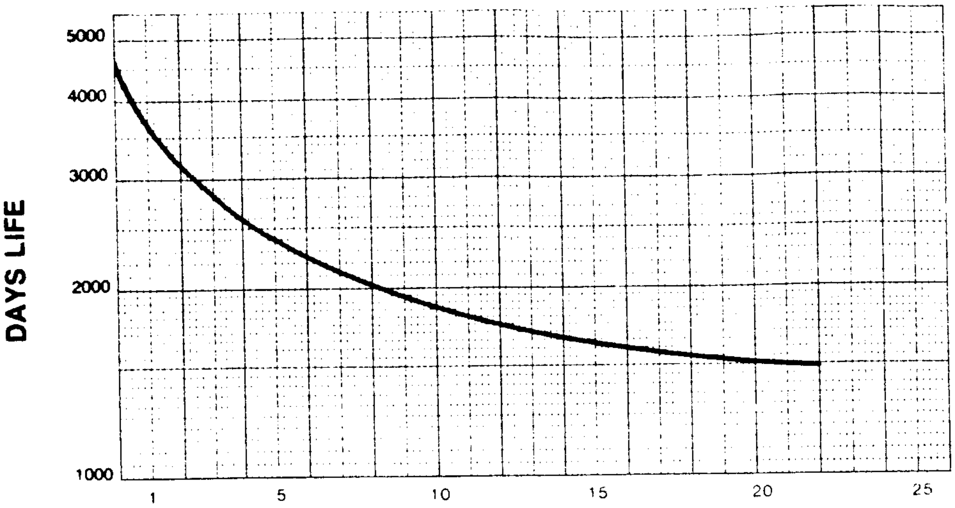
Temperature Adjustment



To correct for temperature variances (worst case condition) multiply the batteries rated capacity at 25°C (77°F) by the correction factor above to yield the expected capacity of the battery at a given temperature (internal cell temperature.) To use ambient air temperatures, average the temperature readings over a 24 hour period and use the correction factors above.

Days Life — Shallow Cycle Battery Type

CYCLE LIFE VS. DEPTH OF DISCHARGE
One Cycle/Day-100 Hr. Rate



DAILY AVERAGE DEPTH OF DISCHARGE
(% of rated capacity)

Accessories

BATTERY RACKS: 1-TIER, 2-TIER, 2-STEP, 3-TIER, 3-STEP AND 2-TIER/2-STEP STANDARD RACKS FOR "E" SIZE ARE SUITABLE

	CAT.NO.	ALT. CAT. NO.
HYDROMETER	81332	00168
HYDROMETER HOLDER	27717	—
THERMOMETER	88330	00030
CELL NUMBER SET:		
1-30	49930	
1-60	49931	
1-120	49932	
1-240	49933	
SPILL PROOF VENT	00431	
DH-5 REQUIRES ADAPTOR	89725	
MARINE SPILL PROOF VENT	00123	
CARRYING HANDLE FOR DH-5	00068	
FLAME ARRESTOR	89660	
FLAME ARRESTOR/ LEVEL INDICATOR FOR DH-5	89695	

JUMPER CONNECTORS NO. 8 AWG			CAT. NO.
14 in.	360mm	Bolt on Lugs	00114
24 in	600mm	Bolt on Lugs	00121
36 in	900mm	Bolt on Lugs	00115
56 in	1450mm	Bolt on Lugs	00116
75 in	1900mm	Bolt on Lugs	00117
JUMPER CONNECTORS NO. 6 AWG.			
14 in	360mm	Bolt on Lugs	00287

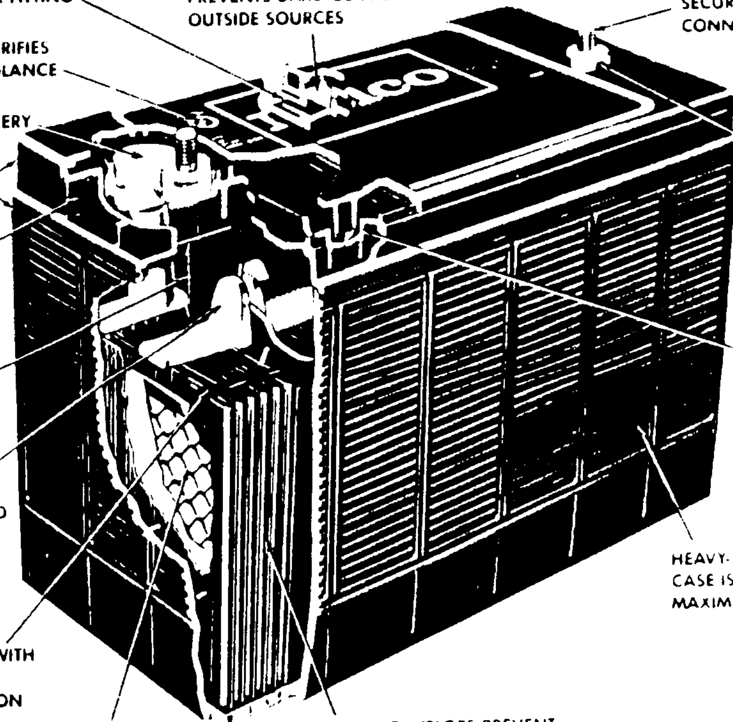
EXIDE
101 Gibraltar Road Horsham PA 19044
215 674-9500 Telex 83-4260 TWX 510-665-7247

Form No. 8215—10-82 Printed in USA

A Ne
Concept For Energy Storage

- **NO MAINTENAN REQUIRED**
  Never Needs Water
- **LIGHT WEIGHT**
  Less Shipping Cost
- **COMPACT SYSTEM SIZE**
  Better Space Utilization
- **WROUGHT GRID CONSTR ION**
  Long Service Life
- **FEWER INTERCONNECTIONS**
  Increased Reliability—Less Power Loss
- **VALUE PRICED**
  More Power Per Dollar

Delco Remy has been a leader in battery manufacturing for over fifty years. Innovative technology, advanced production facilities, and a continued effort to meet customer needs have made Delco batteries the largest selling brand today. In 1970, Delco Remy solved the battery maintenance problem by developing the first truly maintenance-free battery using a unique wrought lead calcium grid construction. Since its introduction, Delco's maintenance-free line has grown with the addition of the first maintenance-free cycling battery, the first maintenance-free motive power battery, and the latest addition—the first maintenance-free photovoltaic battery, the Delco 2000. It has the same patented construction for improved performance and life with no periodic maintenance. And, the Delco 2000 is designed exclusively for today's energy storage systems.



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MAINTENANCE-FREE PHOTOVOLTAIC BATTER

Delco 2000

To assure pendable, efficient and economical operation, the load, the environment, the system and the battery must be integrated into a single unit. The following specifications and data should be considered when applying the Delco 2000 to your photovoltaic system.

REPLACEMENT AND WARRANTY

Recommended replacement batteries are the Delco 1150 or 1250 and are available through AC-Delco worldwide. Contact your system supplier for the location of the nearest AC-Delco outlet. Warranty is handled through the system supplier and all inquiries should be directed to that supplier.

TESTING AND CHARGING

For general diagnostic purposes use the "built-in" hydrometer.

Green dot visible:
Generally signifies the battery has a state of charge 65% or higher.

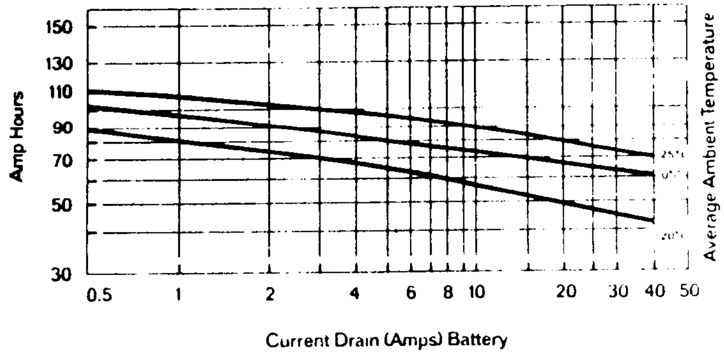
Dark-Green dot not visible:
Generally signifies the battery has a state of charge less than 65%. It DOES NOT signify a faulty battery.

If necessary, the battery may be charged by conventional equipment and methods. To obtain more detailed testing and charging procedures, contact your system supplier.

Delco Remy Division of General Motors Anderson, IN Made in U.S.A.

SYSTEM SIZING

To determine the battery's rated ampere-hour capacity: (1) Estimate the current draw per battery. (2) Estimate the operating temperature. (3) Read the ampere-hour capacity from the appropriate curve. Example: A battery with a current draw of 2 amps and operating at 0 C, has about a 91 rated ampere-hour capacity.



For maximum battery life:

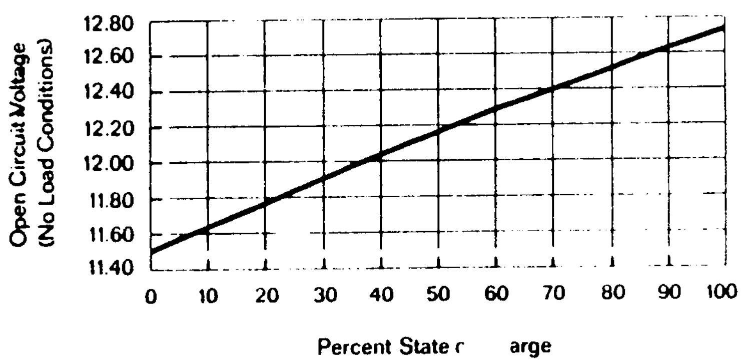
- Daily discharge depths should not exceed 15% of th battery's rated ampere-hour capacity.
- The battery should maintain a minimum of 50% stat charge during worst operating conditions (winter, nc sun days, etc.). Occasional deep discharges below 50% state of charge are allowable, but not recommended for prolonged periods of time.
- Best operation is achieved between the temperature of −5 C and 35 C.
- Multiple batteries may be used in parallel to obtain proper operating conditions.
- The battery is equipped with an external vent tube tc allow for remote venting, if necessary.
- Sealed maintenance-free connections are recommended to limit interconnection power losses and inhibit corrosion build-up.

Applying the Delco 2000

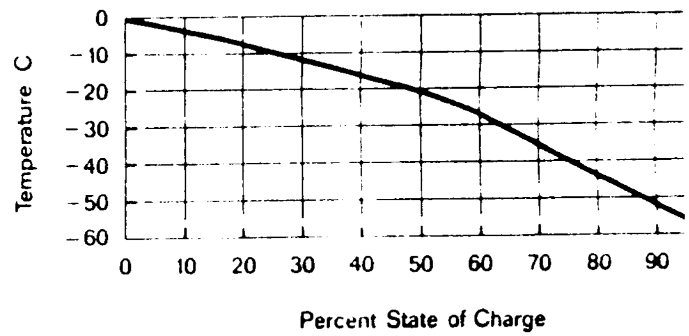
TECHNICAL SPECIFICATIONS

Output Rating: 12 volts—nominal
Capacity: 105 ampere hours (100 hour rating @ 25 C)
Self Discharge Rate: 4 ampere hours per month @ 27 C
Dimensions: length-330.2 mm, width-172.0 mm, height-238.8 mm, weight-27.3 Kg
Voltage Regulation: Suggested setting of 14.1 volts @ 27 C. For every C increase, lower setting by 33mV. For every C decrease, raise setting by 33mV.

State of Charge Determination:
Correlate to open circuit voltage @ no load condition.



Electrolyte Freezing Point:
Correlate to state of charge.



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Meter Box (MB)

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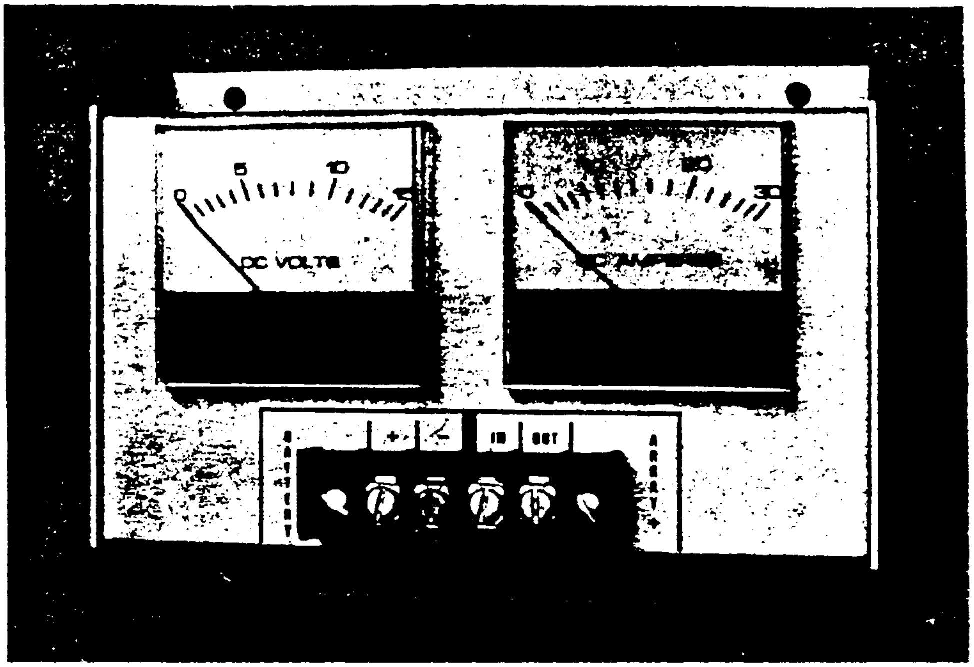


DESCRIPTION

The METER BOX (MB) contains two meters for monitoring system voltage and current, providing valuable information on the performance and status of an alternate energy system. The meters are available for 12 and 24 volt systems in 10 or 30 amp versions.

The METER BOX utilizes 2% pivot and jewel meters, with an expanded scale voltmeter. They are housed in an anodized aluminum chassis, suitable for indoor wall mounting with a terminal block for up to 10 gauge wire or a spade connector, providing simple installation.

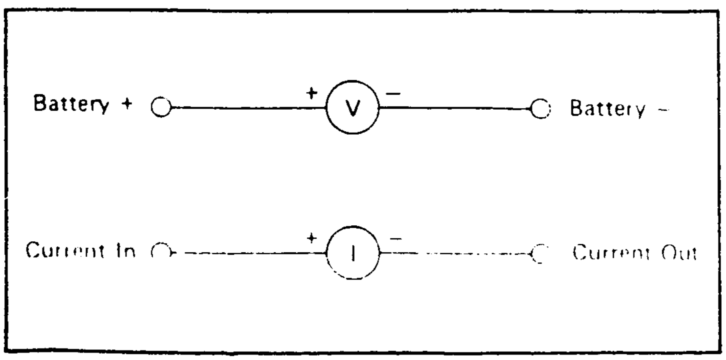
PART NUMBERING KEY

EXAMPLE:

Model
Voltage
Current

MB – 12/10

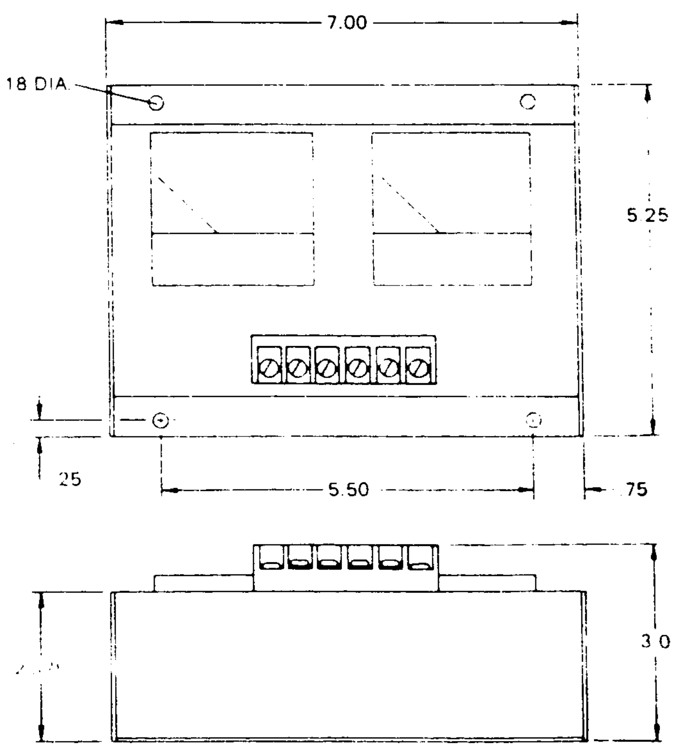
Model	Voltage	Current
MB	12	10
	24	30



Block Diagram - MB

DIMENSIONS

(In Inches)



WT. 1 lb.

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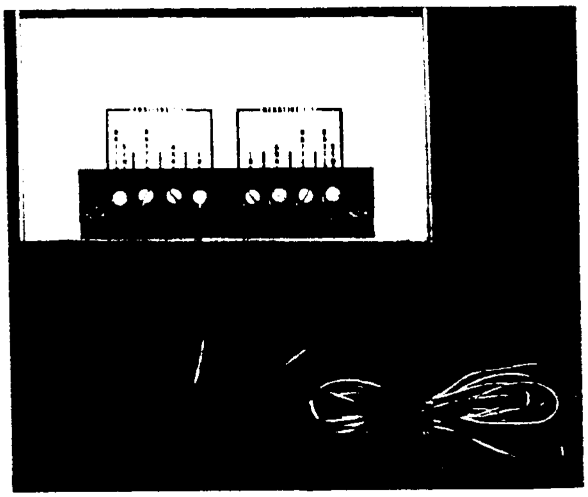
MSR24S10
MSR36S10
MSR48S10

SOLAVOLT™
INTERNATIONAL
P O BOX 2934 ● PHOENIX, ARIZONA 85062 ● (602) 231-6400

VOLTAGE REGULATOR FOR PHOTOVOLTAIC POWER SYSTEMS



These voltage regulators are designed to prevent batteries from overcharging when used in a photovoltaic system. Control is attained by partially disconnecting the photovoltaic array from the battery when the battery is fully charged. When not fully charged, the battery receives full array current. When it approaches 100% charge, the regulator automatically switches to a trickle-charge mode. Switching between full-charge and trickle-charge is accomplished with a mechanical relay rated at 500,000 cycles at 30 Adc and derated to 10 amps for increased reliability.

Voltage regulators are available at 12, 24, 36 and 48 Vdc. Other voltages are available as custom options.

FEATURES

- Temperature Compensation
- Series Regulation (Array Shedding)
- Low Battery Voltage Load Disconnect (Optional)
- Water Tight Box (Optional)
- Blocking Diode Not Required
- 60 mA Current Drain (Average)
  0.72 Watts Power Dissipation (12 V)
- Controls Up To 10 A of Array Current
  (4 MSP43E40 Modules in Parallel)
- Equalizing Charge Automatically Applied to Battery
- Connection Via Terminal Strip

FIGURE 1 – BATTERY TEMPERATURE CHARACTERISTICS

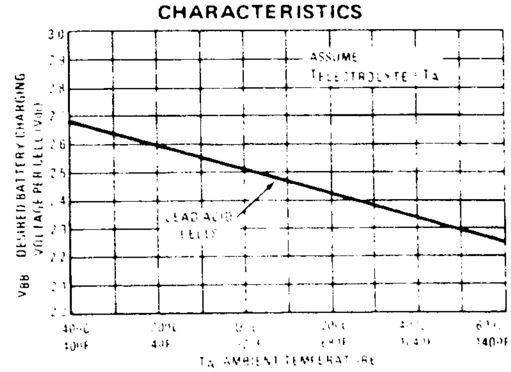
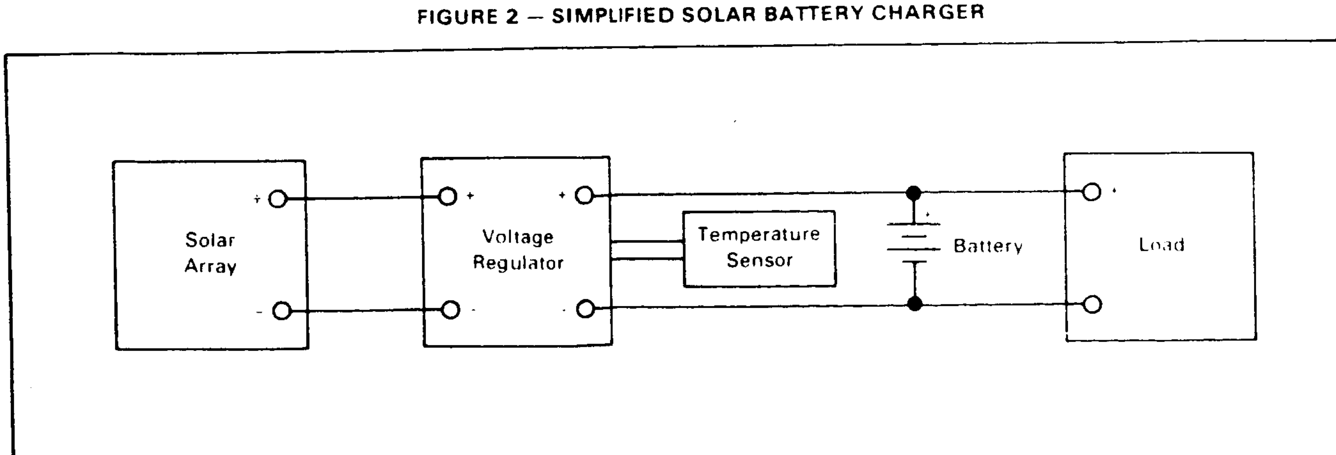


FIGURE 2 – SIMPLIFIED SOLAR BATTERY CHARGER



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MAXIMUM RATINGS

Rating	Symbol	Limit Min	Limit Max	Unit
Maximum Operating Regulator Temperature	T	-40	60	°C
Storage Temperature	T_A	-65	60	°C

Definitions:

- I_{Max} Maximum regulator current ≈ I_{SC} of array
- V_{Set} Factory set regulator output voltage
- I_Q Quiesent Current — Relays Off

ELECTRICAL CHARACTERISTICS (T_A, T_S = 25°C unless otherwise noted)

Part Number	Nominal Voltage	I_{Max}** Amps 25°C	V_{SET} (Vdc) Full-Charge 25°C	V_{SET} (Vdc) Trickle Charge 25°C	I_Q mA Typ*	I_Q mA Max
MSR12S10	12	10	14	15	6.0	12
MSR24S10	24	10	28	30	8.0	15
MSR36S10	36	10	42	45	10	20
MSR48S10	48	10	56	60	12	20

*0°C T_A 50°C **Short circuit current (I_{SC}) of array at 100 mW/cm² must be less than this rating

FIGURE 3 — 12 V REGULATOR OUTPUT

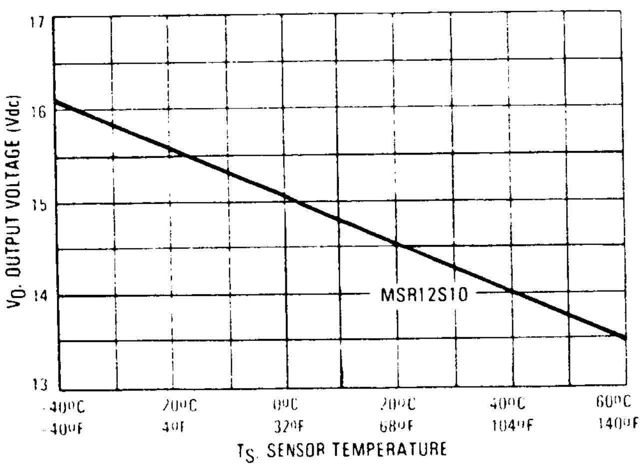

FIGURE 4 — 24 V REGULATOR OUTPUT

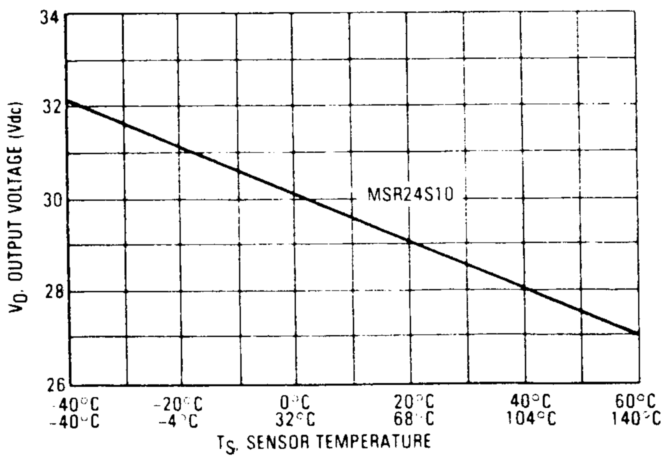

FIGURE 5 — 36 V REGULATOR OUTPUT

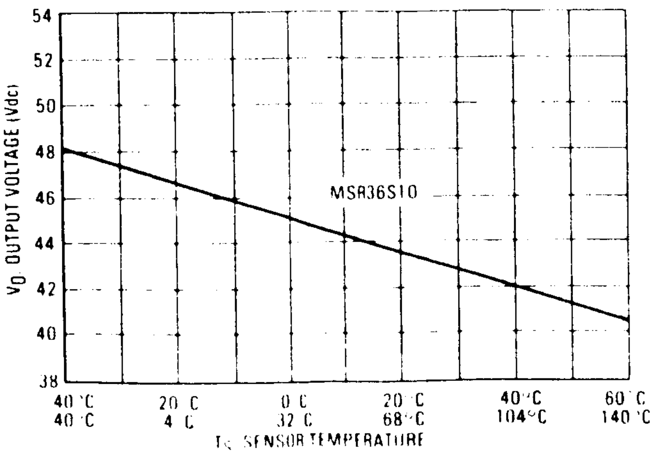

FIGURE 6 — 48 V REGULATOR OUTPUT

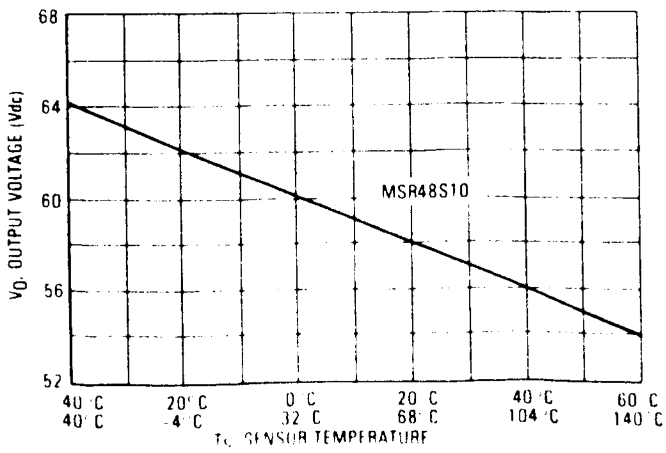

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FIGURE 7 — SYSTEM INTERCONNECT

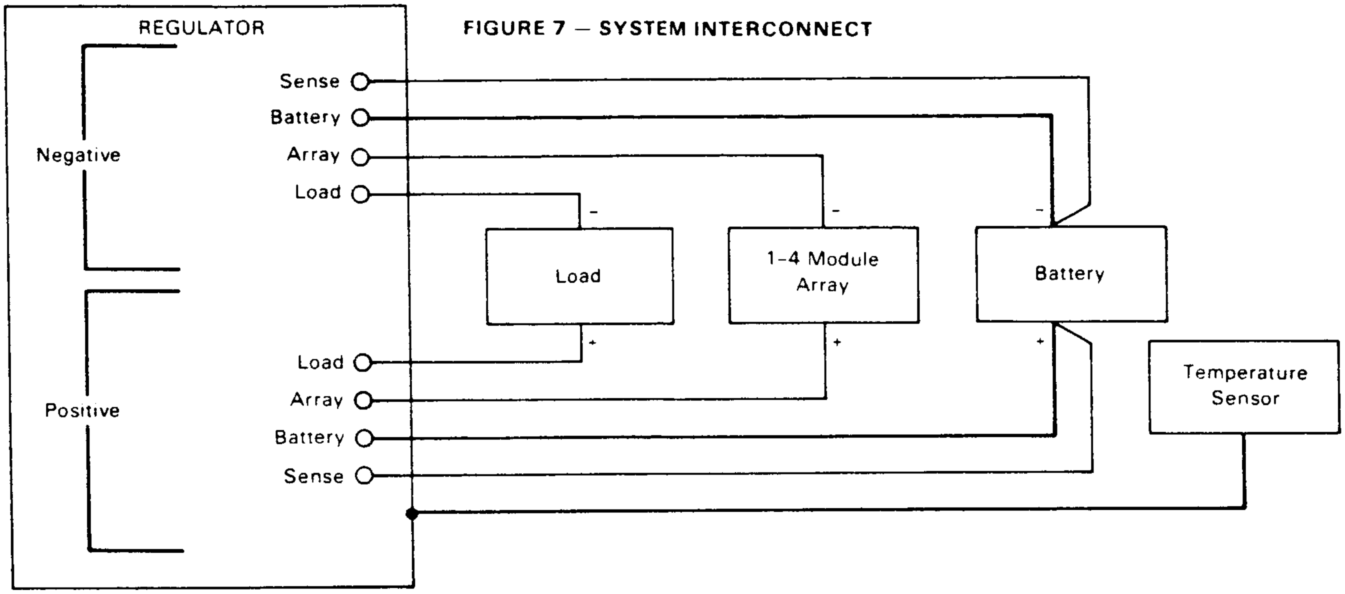
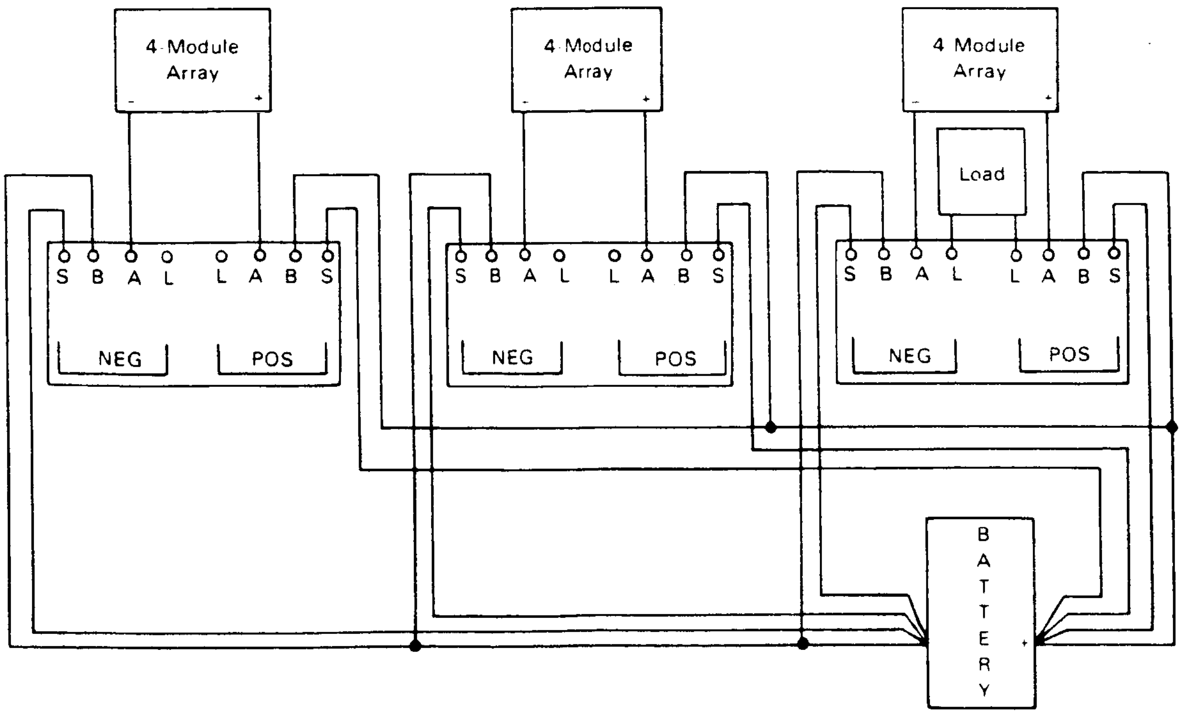


FIGURE 8 — LARGE SYSTEM INTERCONNECT



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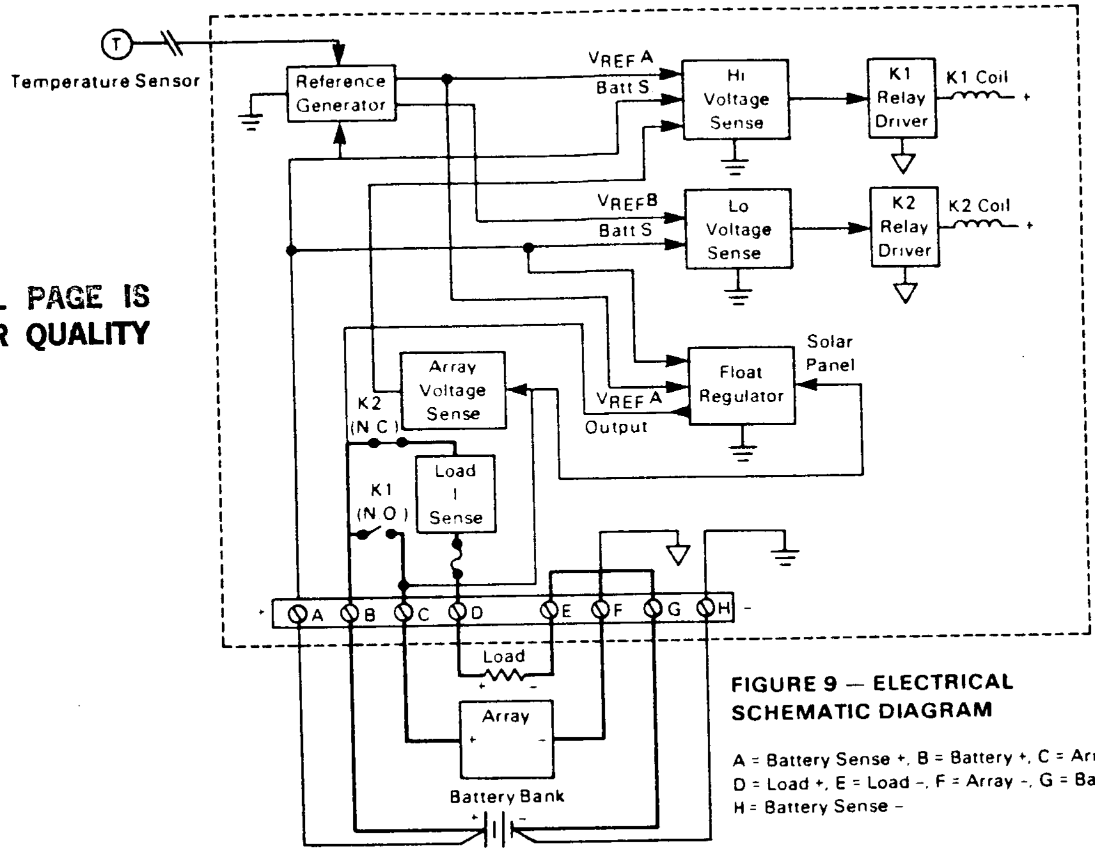
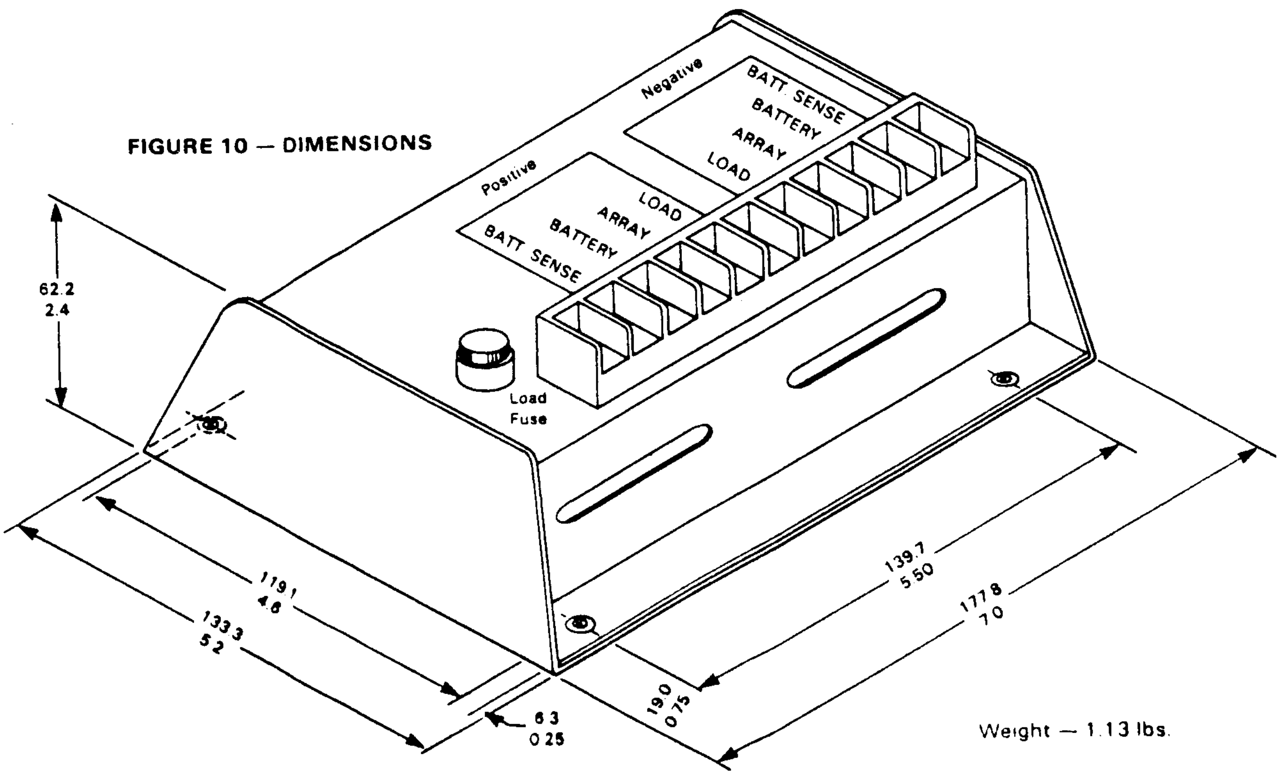


FIGURE 9 — ELECTRICAL SCHEMATIC DIAGRAM

A = Battery Sense +, B = Battery +, C = Array +, D = Load +, E = Load –, F = Array –, G = Battery –, H = Battery Sense –

FIGURE 10 — DIMENSIONS



Weight — 1.13 lbs.

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FIGURE 11 — SMALL SYSTEM DIAGRAM

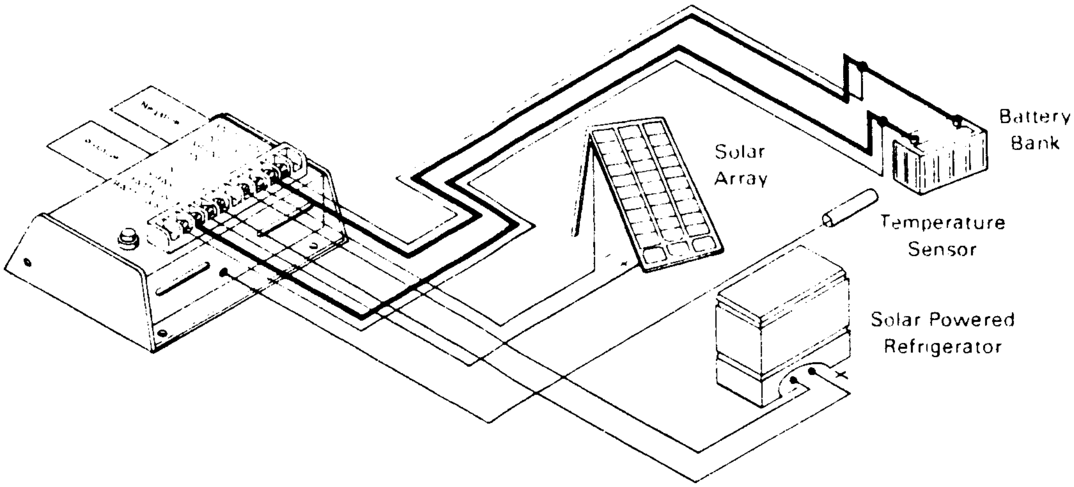
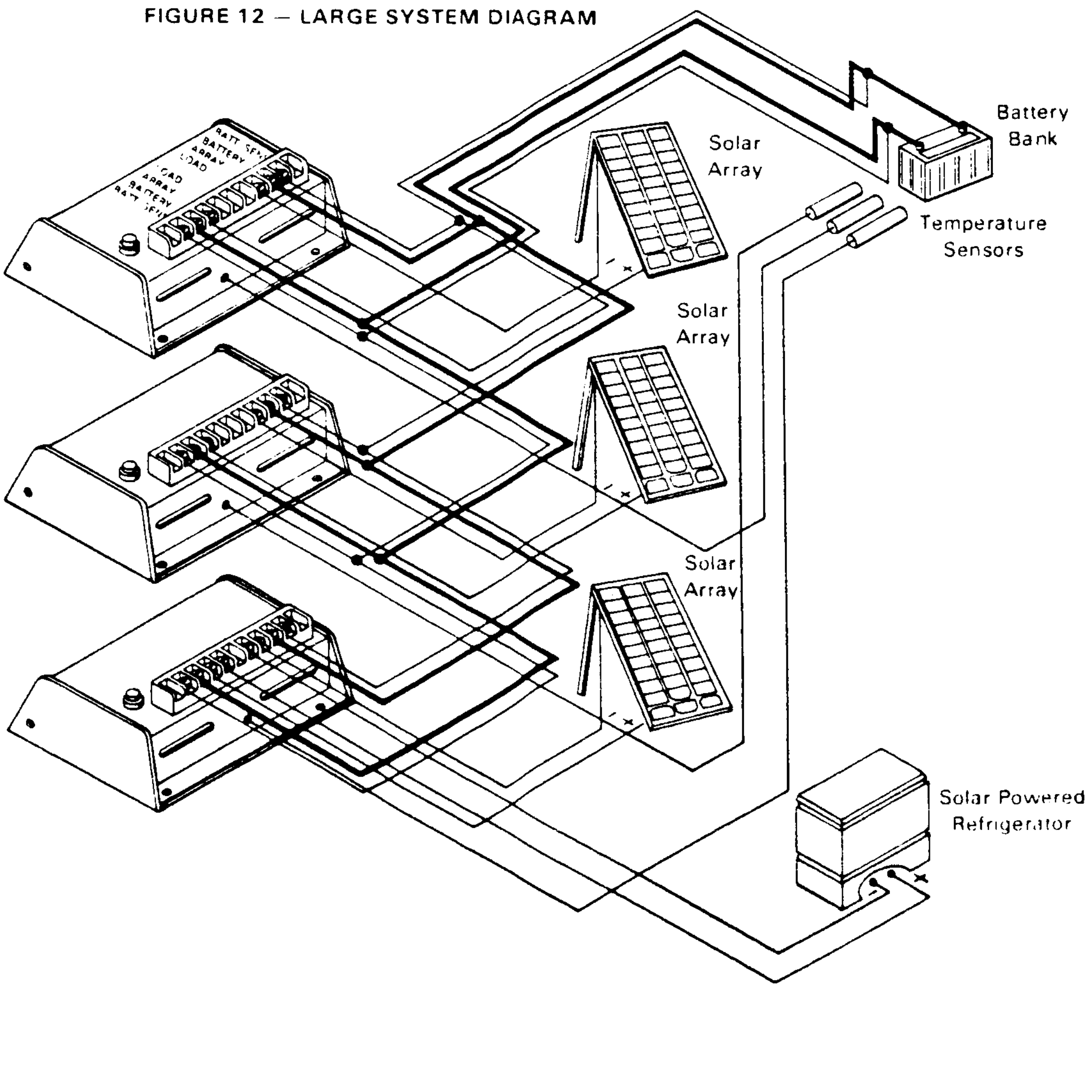


FIGURE 12 — LARGE SYSTEM DIAGRAM



Battery Saver™ (BS)

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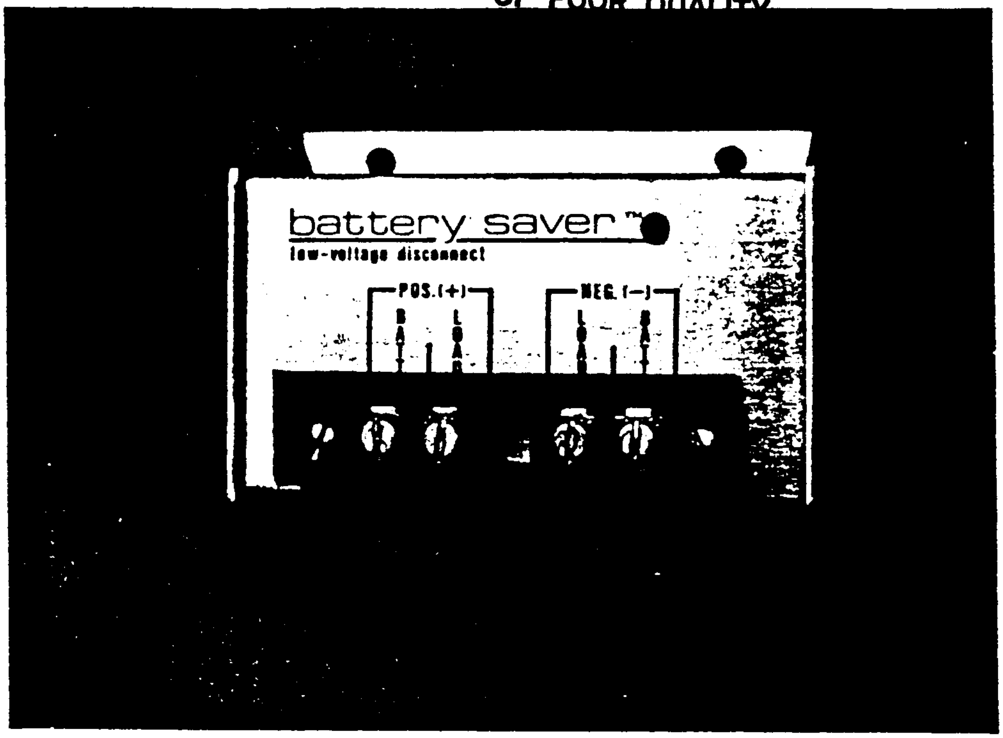


DESCRIPTION

The BATTERY SAVER (BS) is a versatile device for the protection of batteries from voltage extremes. It can be used in systems to disconnect a load, provide a low or high voltage alarm, or start a generator. The BATTERY SAVER is available for 12, 24, 36 and 48 volt systems.

The BATTERY SAVER consists of a relay with a voltage sensing circuit and a red light to indicate operation. It is housed in an anodized aluminum chassis suitable for wall mounting with a terminal block for up to 10 gauge wire or spade connector, providing simple installation.

FEATURES -

* Versatility
* Indicator light
* Input noise suppression
* Time delayed activation
* Reverse polarity protection

OPERATION

NOTE: The standard configuration for the BATTERY SAVER is as a low-voltage load disconnect. The other variations can be ordered as an option.

LOW-VOLTAGE LOAD DISCONNECT- When battery voltage reaches the low voltage threshold, the normally closed relay will energize and open. The red Light Emitting Diode (L.E.D.) on the front panel will light and the load will be disconnected. When battery voltage rises, indicating charging has occured, the load will be automatically reconnected.

OPTION DESCRIPTIONS

A. LOW-VOLTAGE BEEPER- When battery voltage reaches the low voltage threshold, an audible beeper is energized and the red L.E.D. on the front panel will light. The beeper is de-energized when battery voltage rises slightly, usually by turning off one or two major loads.

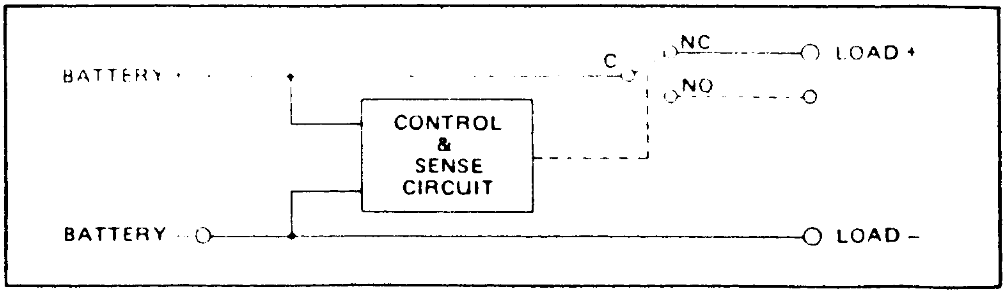
B. HIGH-VOLTAGE BEEPER- The high voltage beeper operation is similar to the low beeper with the exception that the beeper is activated when the battery reaches the high voltage threshold.

C. LOW-VOLTAGE ALARM - This version is for systems requiring a relay contact closure for remote warning of low voltage conditions. When battery voltage reaches the low voltage threshold, the normally closed relay is de-energized, closing the contacts and lighting the L.E.D. on the front panel. A system power failure will also cause a contact closure. When battery voltage rises, indicating that charging has occured, the contacts will open.

D. HIGH-VOLTAGE ALARM - This version is for systems requiring a relay contact closure for remote warning of high voltage conditions. When battery voltage reaches the high voltage threshold, the normally open relay is energized, closing the contacts and lighting the L.E.D. on the front panel. When battery voltage falls, the contacts will open.

E. GENERATOR START- For systems designed with stand-by generator back-up, the BATTERY SAVER can signal when low batteries need additional charging. When battery voltage reaches the low voltage threshold, the normally open relay will energize, closing the contacts and lighting the red L.E.D. on the panel. When battery voltage rises to the reconnect threshold, indicating charging has occured the contacts will open.

F. ADJUSTABILITY OPTION- The set points for all versions can be externally adjustable.

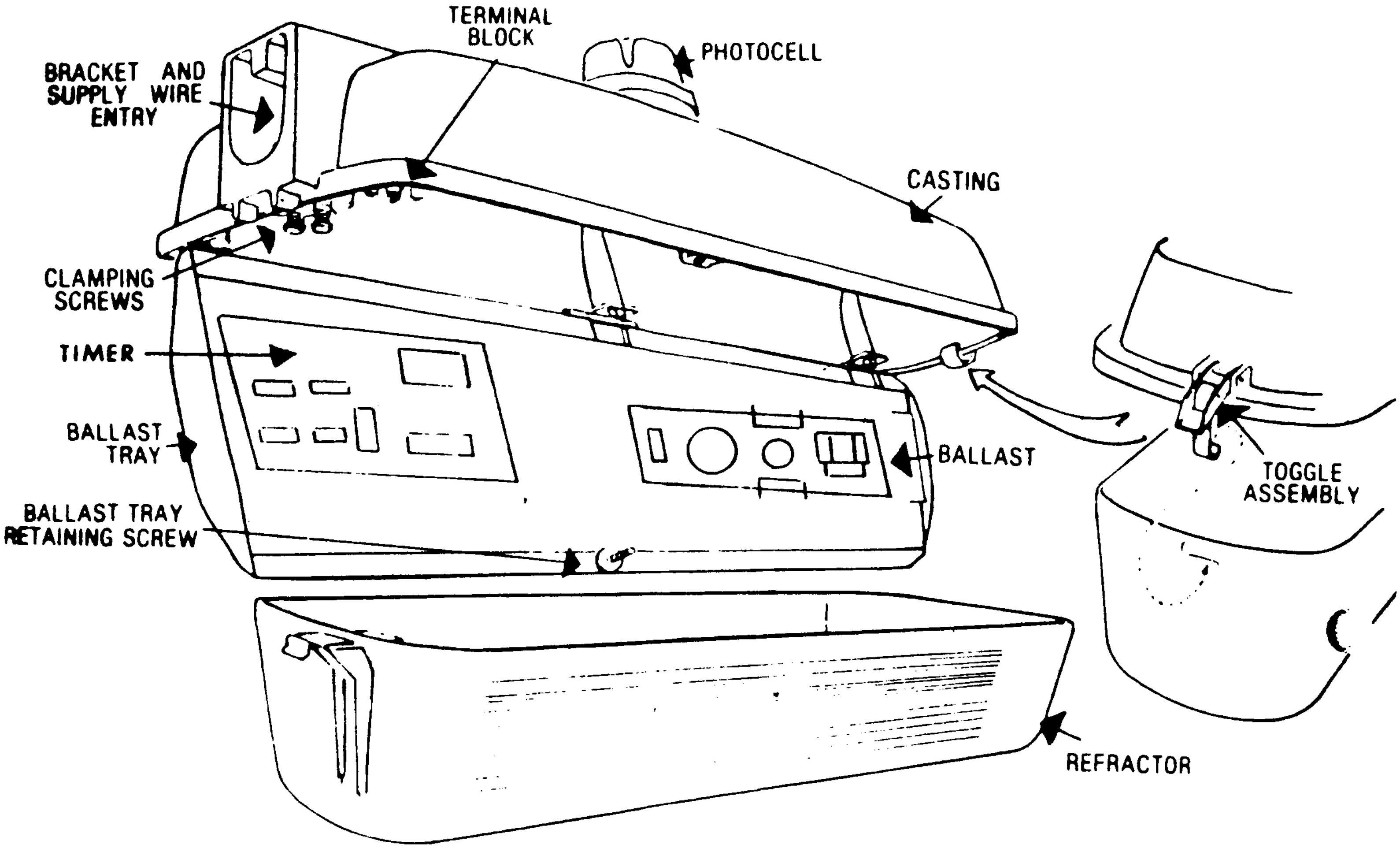


Block Diagram · BS

Installation and Wiring Instructions for

LPS 135 LT
LPS 118 LT

REC



Installation Instructions

1. Check that voltage shown on fixture label matches available line voltage.
2. Fix bracket to wall or pole with tube inclined upwards. Thread supply wire inside tube
3. Remove refractor from fixture. Release ballast tray retaining screw to allow tray to hang open.
4. Loosen clamping screws. Install fixture on bracket, allowing supply wires to pass into fixture. Tighten clamping screws.
5. Connect supply wires to terminal block. Connect ground wire to green grounding pigtail.
6. Close and fasten ballast tray, insuring supply wires are neatly arranged, and are not in contact with ballast.
7. Pass lamp through wire lamp support and insert into lamp socket. Replace refractor
8. Install photocell into receptacle on top of fixture and twist slightly clockwise.

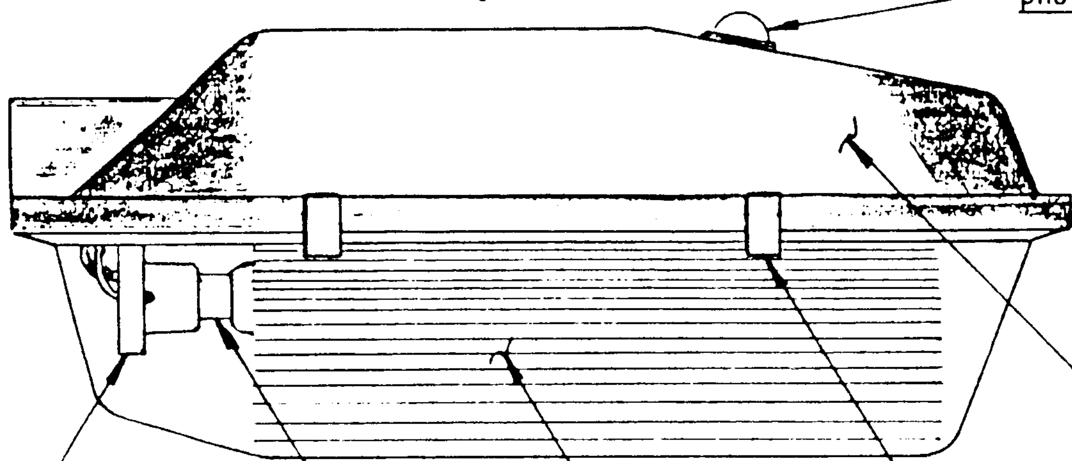
NOTE To test fixture in daylight, photocell must be covered. For most accurate operation the photocell receptacle should first be unscrewed, and relocated so that the arrow points as near "north" as the screw positions allow. Do not turn the receptacle more than 180° in any direction or damage to internal wiring may result

REC SPECIALTIES INC. Camarillo, CA

EXTERIOR STREET/SECURITY LIGHT

LOW PRESSURE SODIUM

WITH AUTOMATIC PHOTOELECTRIC CELL AND TIMER



SPECIFICATIONS:

HOUSING:	cast aluminum
DIFFUSER:	polycarbonate - vandal resistant
MOUNTING:	tenon $1\frac{1}{4}$" pipe
LAMP WARM UP TIME:	7 to 10 minutes at 25° Centigrade
TIMER:	adjustable from 1 to 15 hours (can be by-passed)

MODEL NUMBER	WATTAGE	INPUT VOLTS	CURRENT	DESIGN LUMENS
LPS-118LT	18 watts	12 VDC	2.3 amps	1800 lumens
LPS-135LT	35 watts	12 VDC	3.2 amps	4800 lumens
LPS-218LT	18 watts	24 VDC	1.15 amps	1800 lumens
LPS-235LT	35 watts	24 VDC	1.6 amps	4800 lumens

WEIGHT: approx. 6.6 lbs. (3 Kg)
DIMENSIONS: approx. 16.5" long, 7" wide, 7" deep

REC SPECIALTIES
530 CONSTITUTION AVENUE
CAMARILLO, CA 93010, U.S.A.
(805) 987-5021

DWN. [illegible] 1/26/83		CAT. NO.	LPS
APPRV. [illegible]		DWG. NO.	1-316
DATE:	2/7/83		

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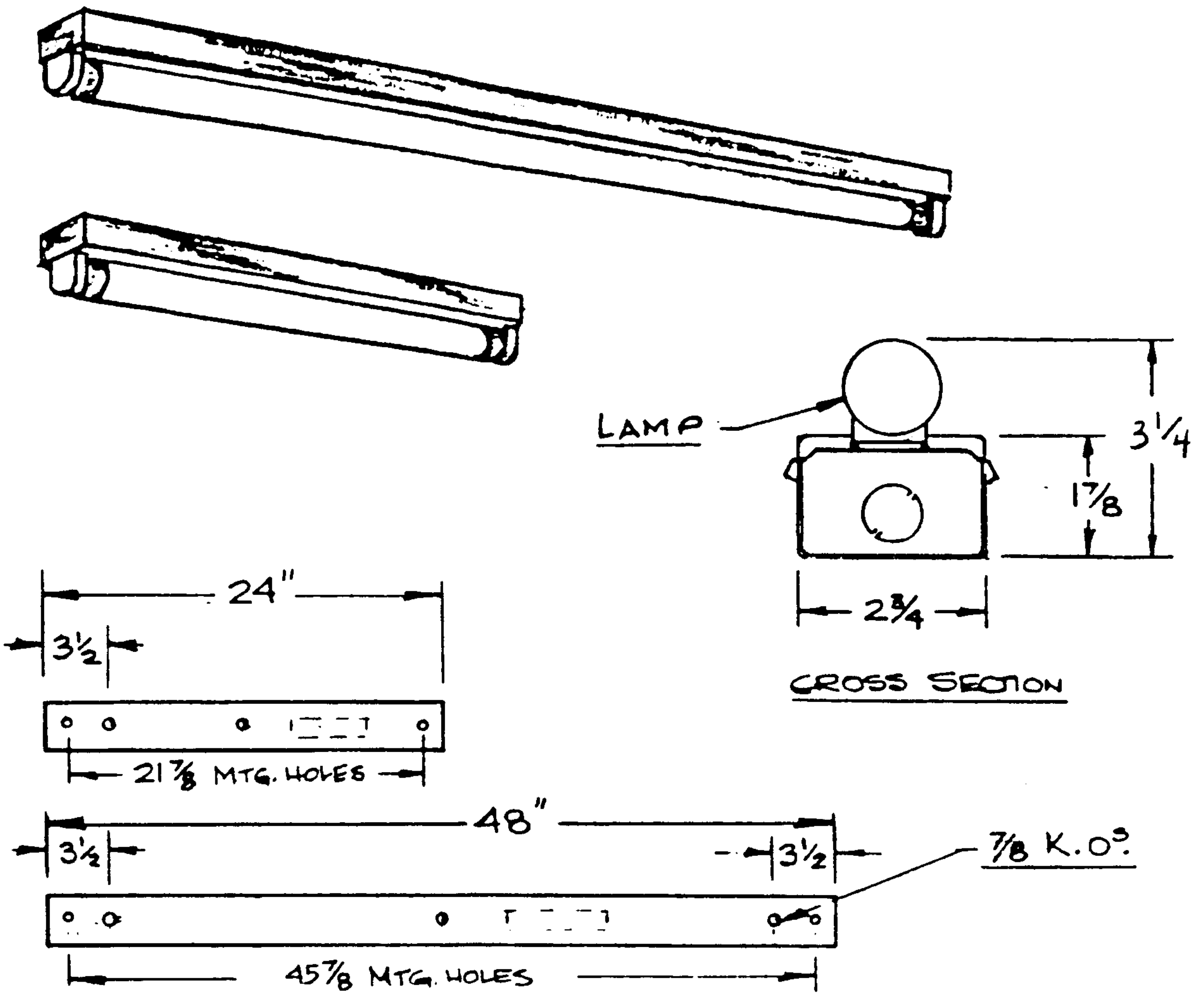


SPECIFICATIONS:

HOUSING - RIGIDLY DIE CONSTRUCTED #22 GA. CRS.
END PLATE - DUAL PURPOSE - END PLATE OR COUPLER FOR CONT. ROW APPLICATIONS.
FINISH - BAKED WHITE ENAMEL 85% REFLECTIVITY.
INVERTER - 12 VDC SOLID STATE, WITH 9' LEADS BLACK +, WHITE −.

153	F40T12 C/W	3.0	48"
151	F20T12 C/W	1.5	24"
CAT. NO	LAMP	AMPS	FIX. LENGTH

REC SPECIALTIES

15155 STAGG ST.
VAN NUYS CA 91405

DWN. [signature] 1/7/80
APPRV. [signature]
DATE 1/8/80

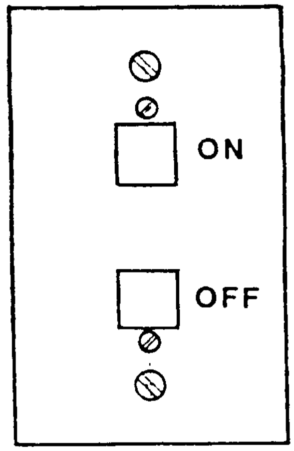
CAT. NO. #151 & #153
DWG. NO.

SunAmp Systems Inc.

PHOTOVOLTAIC PRODUCTS

D.C. SOLID STATE WALL SWITCH AND TIMER

Features:



† Increases system efficiency by assuring that lights and other loads are OFF, after a preset operating period.

† Time delay is settable in digital increments from 3 3/4 minutes to 16 hours.

† Touch ON, touch OFF action.

† 2-way, 3-way and 4-way switch operation is greatly simplified with the addition of "slave" switches.

† Easy installation using standard electrical switch box.

† High stability timing components are used.

† Negligible operating and quiescent current drain.

† Very low switch losses (low R_{sat}).

† Circuitry is protected from lightning induced surges and transients.

† Solid state components eliminate mechanical wearout and arcing problems common with DC switches and relays.

† Two year limited warranty.

Available in the following models:

12 VDC	24 VDC	48 VDC	120 VDC	10 Second Current	Continuous Current
WST- 6-12	WST- 6-24	WST- 6-48	WST- 6-120	8 Amperes	6 Amperes
WST-12-12	WST-12-24	WST-12-48	WST-12-120	15 Amperes	12 Amperes

Slave switch : Model WSTS One model is used for all voltages and currents.

SPECIFICATIONS:

Maximum operating temperature: -30^{o} C to $+55^{o}$C; -22^{o}F to $+131^{o}$F.

Humidity: 0% to 95% (non condensing).

Weights: 8 ounches, maximum.

Dimensions: 4.5" long, 2.75" wide, 2" deep.
(Designed to fit into a standard electrical switch box.)

Timer temperature stability: ± 5% over specified temperature range.

Timer accuracy: ± 5% at 25^{o}C; 77^{o}F.

7702 East Gray Road Scottsdale Arizona 85260 (602) 951 0699

Timer operation and setting information

Switch operates in a normal manner with momentary switch contacts for ON and OFF operation. The ON switch sets (starts) the timer. The load remains ON until the OFF switch is depressed, or the time delay is completed. The desired time delay is selected by an internal 8 position "DIP" switch. The total time delay is obtained by adding the individual switch delays that have been activated. Note Table:

Nominal time delay

Switch Position #	Time Delay
1	3.75 min
2	7.5 min
3	15 min
4	30 min
5	1 hour
6	2 hours
7	4 hours
8	8 hours

Example

1.) For example, if a 4.5 hour delay for a porch light application is desired, switches #4 and #7 would be set to the "ON" position giving a delay or run time of 30 min plus 4 hours or a total of 4.5 hours.

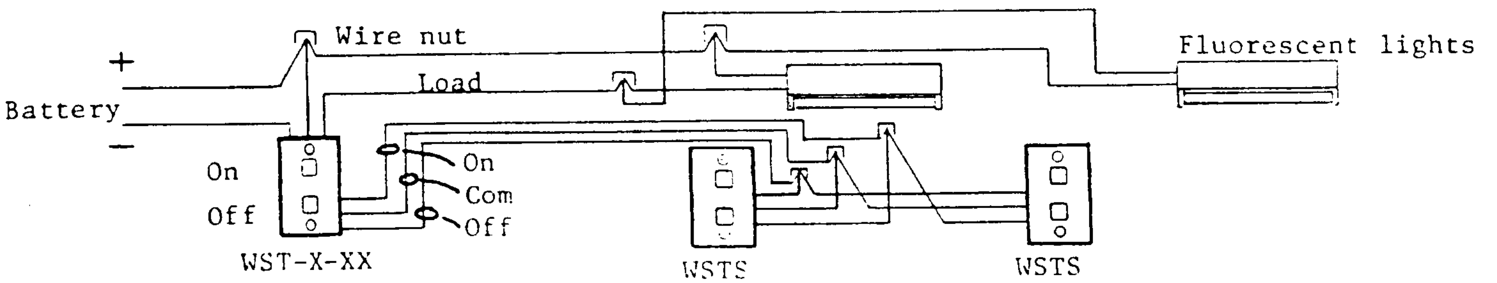
2.) If a hall light is to be on for a maximum of 3 to 4 minutes, then only switch #1 would be set.

3.) A float switch activated water pump needs to run 45 minutes. The float switch is wired in parallel with the ON switch (like a slave switch) and internal "DIP" positions #3 and #4 are set to the ON position.

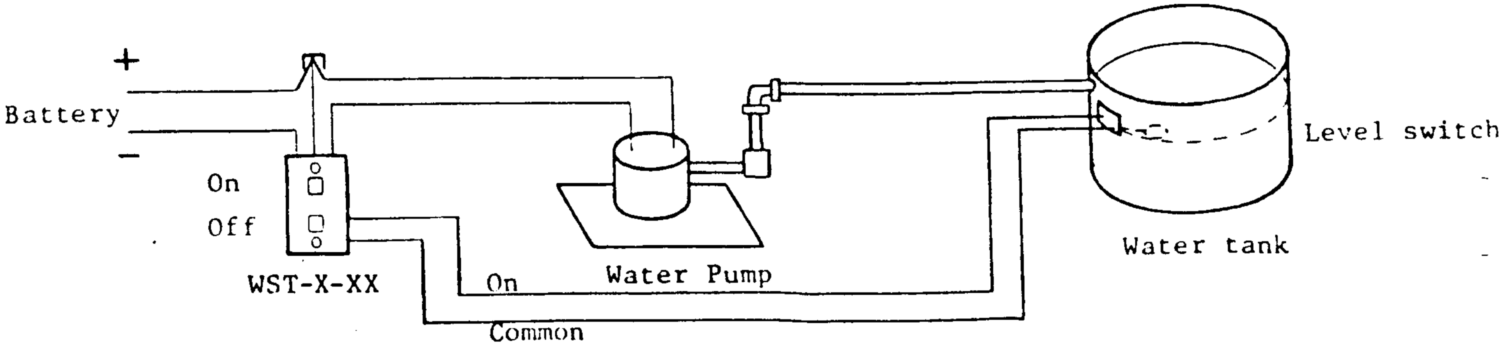
NOTE: Any reasonable number of slave switches may be wired in parallel with the wall switch and timer. Connections are more easily made in a "daisy Chain" manner with multiple slaves.

Typical hookup diagrams

1.) Two lights 3-way switch



2.) Manual/Automatically operating water pump timer



The pump can be turned on or off manually or it will automatically turn on for a preset length of time whenever the level switch senses low water level.

MARVEL

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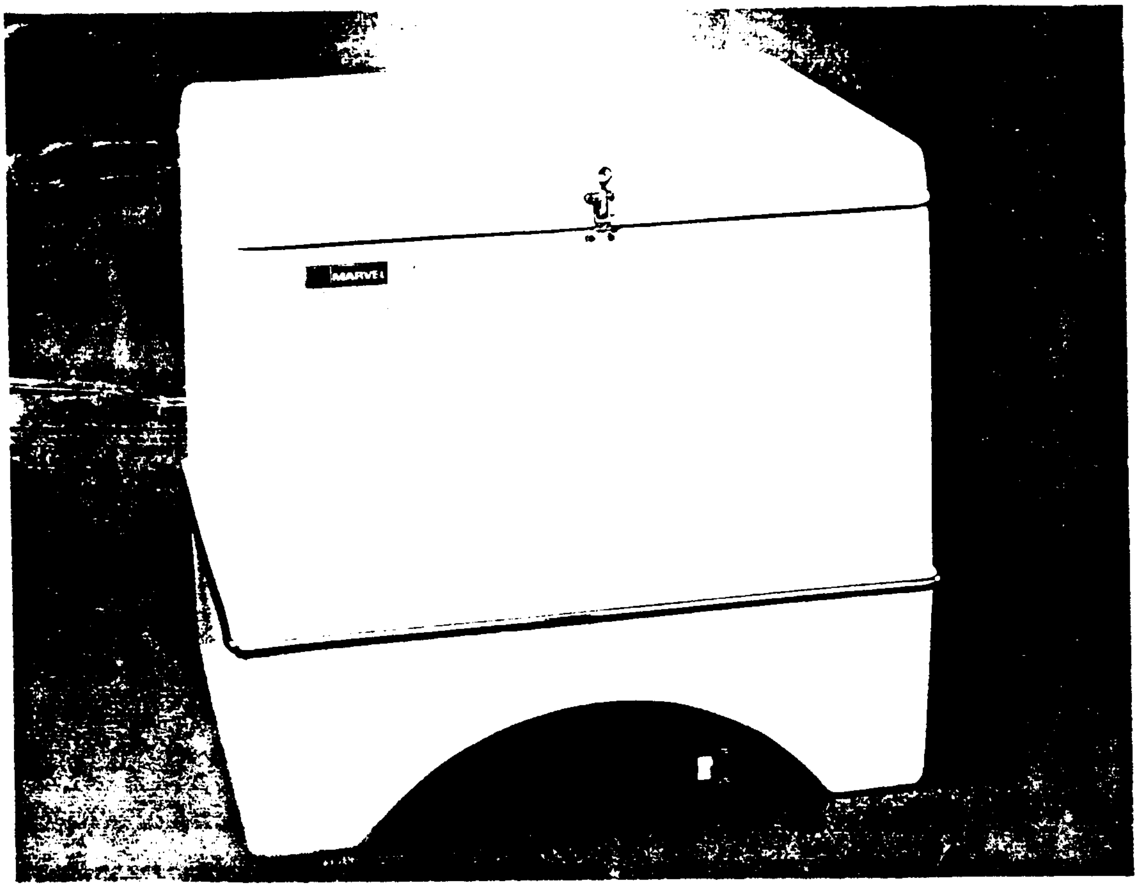
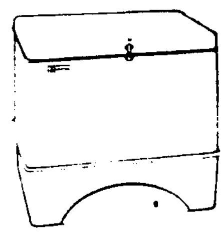
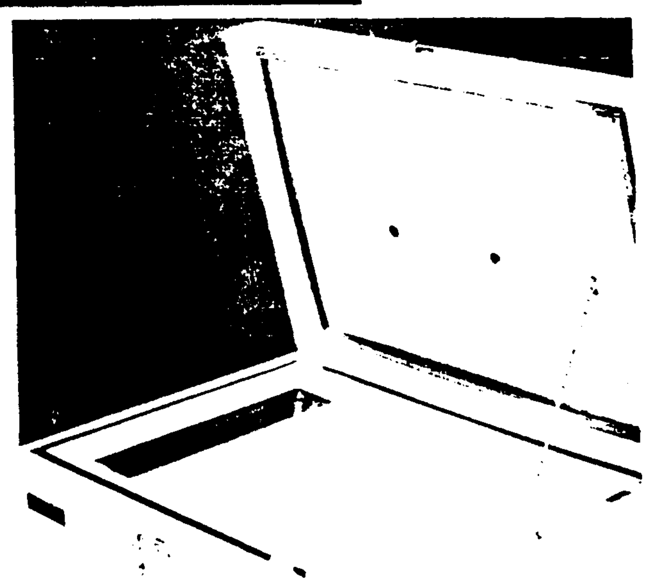
Reliable Bio-Medical Refrigeration

SOLAR
Powered and Extra-Thick Insulation





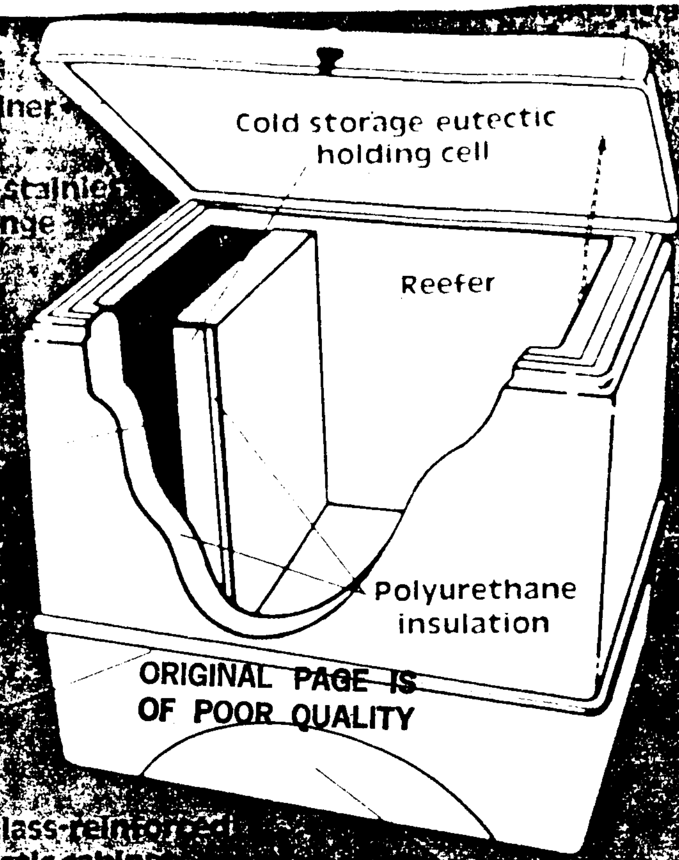


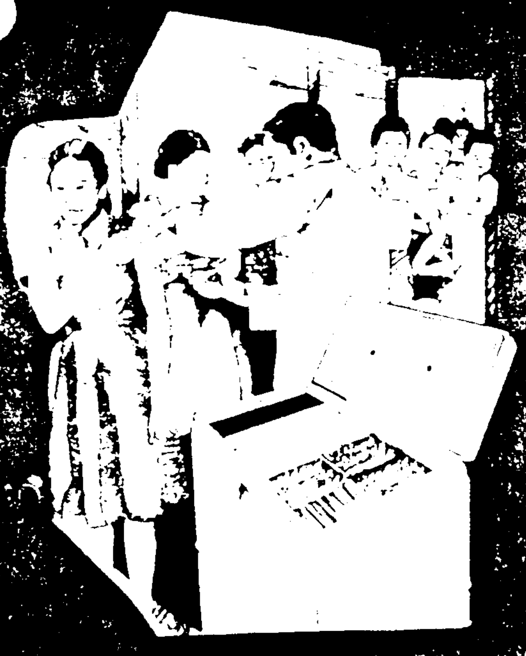
Model 4RTD
Solar 12-volt DC Power 4.0 cubic foot Refrigerator with Freezer, solar insulated for tropical installation, chest type

The Marvel Model 4RTD Solar refrigerator provides long term highly efficient refrigeration for cold storage of bio medical supplies or food products in areas where conventional grid power is unavailable or unreliable. The Model 4RTD has the most efficient power consumption factor of any refrigeration system available for its size. It is designed for commonly available photovoltaic 12 volt DC batteries. The rugged Model 4RTD is constructed of state-of-the-art non-ferrous materials for physical and performance reliability in harsh environments. It includes a cold storage cell for utmost efficiency. Marvel's 4RTD was designed to pass the rigid "cold chain" standards of operation set by the World Health Organization (WHO) and the Center for Disease Control. National Aeronautics and Space Administration, Lewis Research Center (NASA) tested the 4RTD on behalf of WHO.

Features

- Power Source: photovoltaic 12-volt DC batteries are rechargeable by solar array, diesel generators and 115-volt battery charger.
- Low power consumption
- Cold storage eutectic cell provides refrigeration for long periods of time with no compressor operation
- Self-contained battery storage compartment
- Foamed-in-place, thick-walled polyurethane insulation
- 3 cubic foot refrigerator compartment (85 liters)
- 1 cubic foot freezer compartment (28.3 liters)
- Can operate for years with preventive maintenance
- Tough fiberglass-reinforced ABS plastic refrigerator cabinet and top door
- Chromed brass and stainless steel hardware
- Rugged, efficient and reliable





Specifications

Dimensions

External:
L 82.0 cm X H [illegible] cm X D [illegible] cm
(L 32-1/2" X H [illegible] X D [illegible])
Freezer Interior:
L 9.5 cm X H 40.0 cm X D 46.5 cm
(L 3-3/4" X H 15-3/4" X D 18 [illegible])
Reefer Interior:
L 49.5 cm X H 40.0 cm X D [illegible]
(L 19-1/2" X H 15-3/4" X D 18 [illegible])

Capacity

Freezer: 28.3 liters (1 cu. ft.)
Reefer: 85 liters (3 cu. ft.)

Weight

55 Kg (121 lbs.)

Materials

[illegible] thermo-ABS refrigerator plastic and fiberglass-reinforced [illegible] designed for use [illegible] environments
Chromed brass and stainless hardware
Magnetic gasket for positive seal
[illegible]

Electrical Protection

[illegible] 10.8 VDC [illegible] VDC
[illegible] 16.0 VDC
[illegible] amperes
[illegible]
Reverse voltage protection

Refrigeration System

[illegible] amperes
[illegible] consumption
[illegible]
[illegible] consumption
[illegible]
[illegible] 800 BTU

Performance Requirements

[illegible]

MARVEL DIVISION

[illegible] CORPORATION

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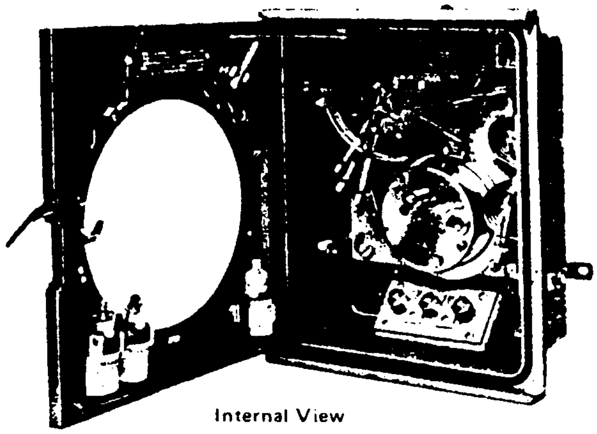
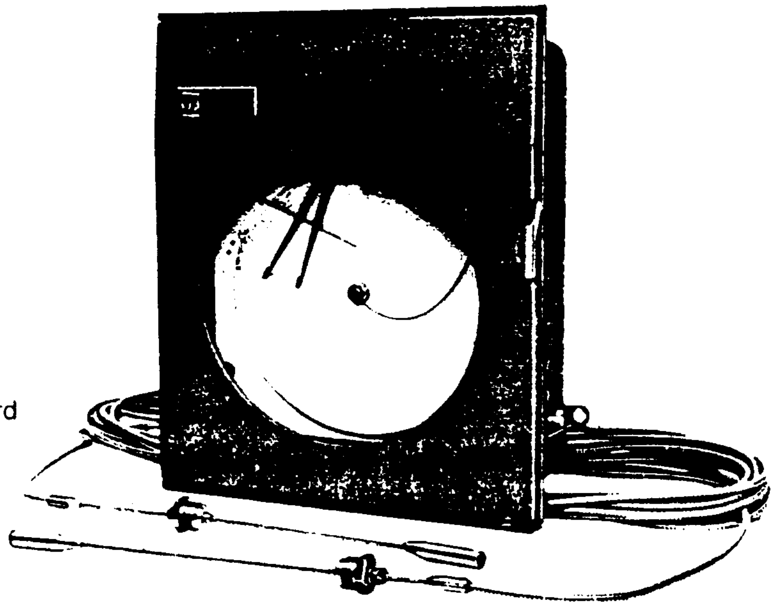
Gas Actuated Recorders

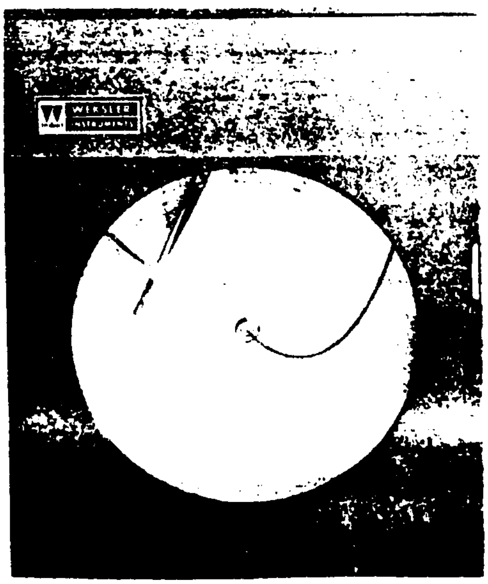


Internal View
of 3 Pen Recorder
Catalog No. 08G3

- Range Limits 200°F to +1200°F (129°C to +649°C)
- Gray-Green Texture Finished Aluminum Case – Rust, Corrosion and Moisture Proof
- Universal Brackets Allow Surface or Flush Panel Mounting
- Stainless Steel Bourdon Tube
- Stainless Steel Large Volume Bulb
- Five Feet of Stainless Steel Capillary Tubing with Interlocking Stainless Steel Armor, Type E Standard
- Universal Connection Allows for Back or Bottom Positioning of the Capillary
- All Stainless Steel Movement, Connecting Link and Pen Arm
- Capillary Type Pens Standard – Fiber Tip and Continuous Feed Pens Available
- Up to 2 Pens Available on 6", 3 Pens on 8" and 4 Pens on 10" and 12" Chart Size Units
- All Portable and 6" Recorders with Electric Chart Drives are Supplied with 6 Feet of 3 Wire Power Cord



10" Two Pen Remote Reading Recorder
with Sliding Union Bulbs
Catalog No. 10G2-N3B

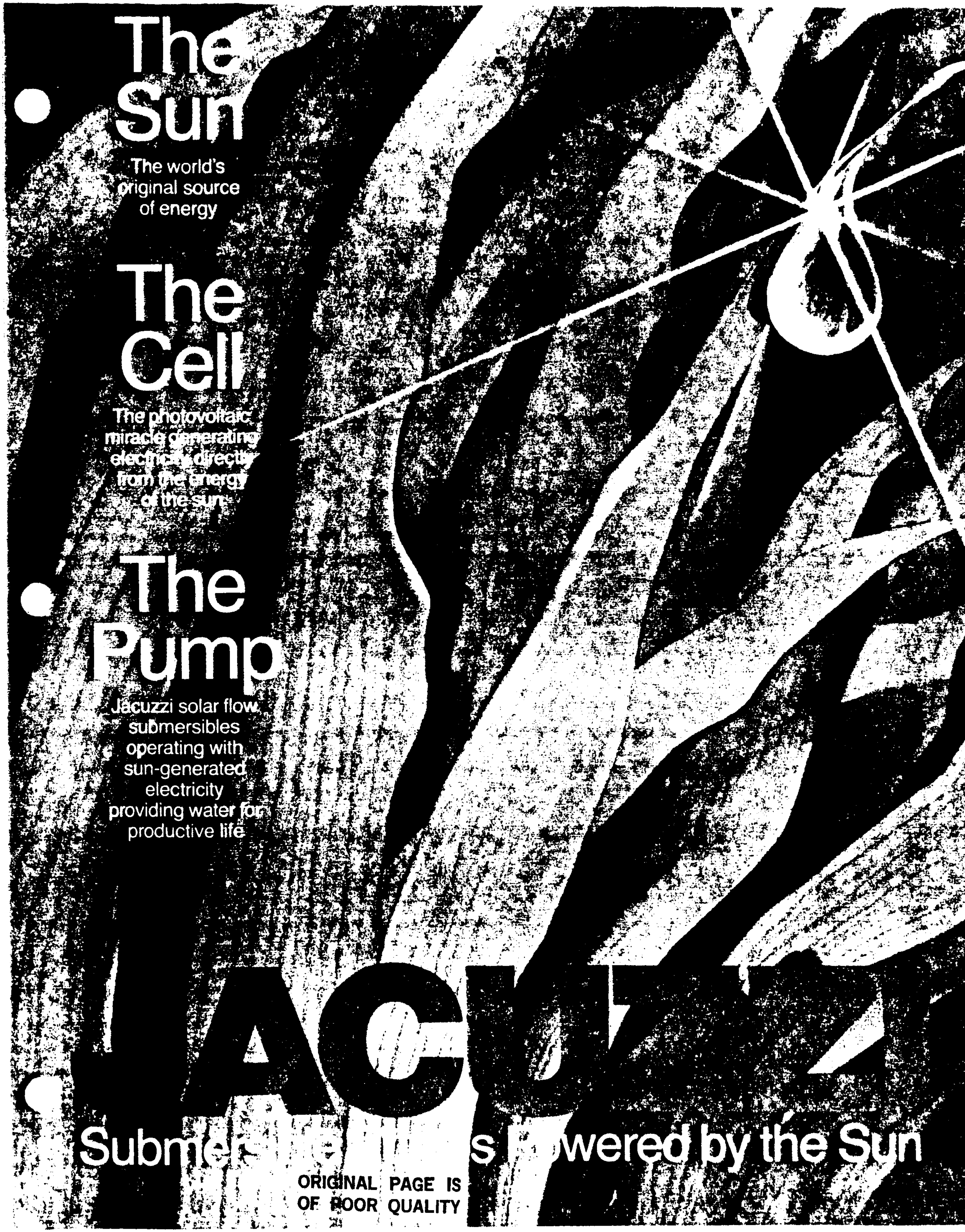


12" One Pen Recorder
Catalog No. 12G1

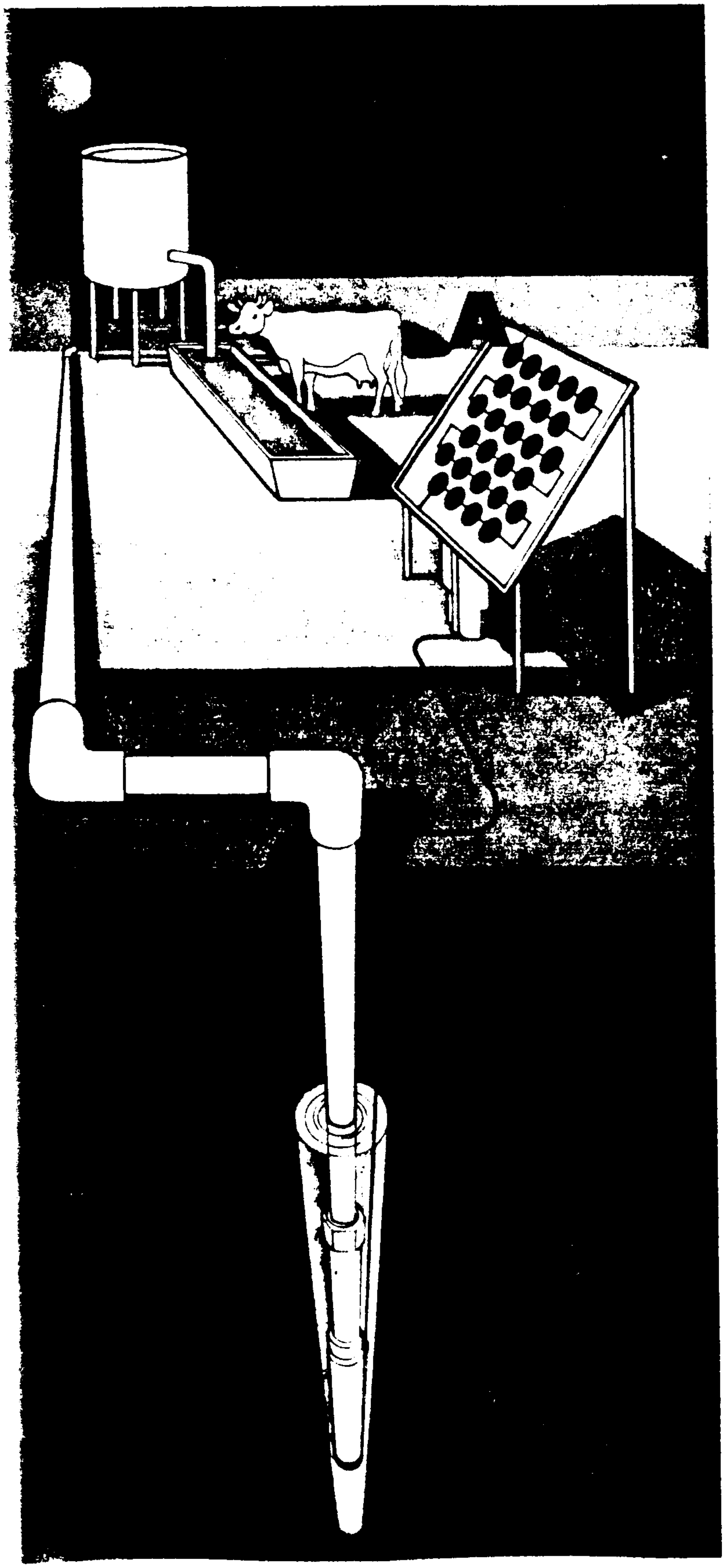
Note: Cases are designed to accommodate temperatures from 20°F to +150°F (29°C to +66°C)

HOW TO ORDER

add the following to Catalog No.
Range (page 26)
Connecting Tubing Length & Type (page 31)
Variations from standard, if any
Bulb Fitting Type, Length & Material (see page 31)
Clock: 24 hr electric is std., 7 day no charge, mechanical is optional extra
Case style: Surface, Flush Mounted or Portable


The Sun
The world's original source of energy
The Cell
The photovoltaic miracle generating electricity directly from the energy of the sun
The Pump
Jacuzzi solar flow submersibles operating with sun-generated electricity providing water for productive life
ACU
Submer
wered by the Sun

The Simple Basics of Solar Pumping



A solar powered pumping system is an economical alternative to other methods of supply where small irrigation or drinking water requirements are beyond the availability of utility power. A typical system can be as simple as solar panels connected directly to a pump, or may include components to better receive the sun's rays and/or store the energy during periods of darkness.

A The photovoltaic cells are connected in multiples, both in parallel and in series, to produce direct current power which varies during the day in relation to the intensity of the sun.

B The array (several panels of photovoltaic cells) is sized to meet water requirements and mounted to maximize the incoming rays of the sun.

C Jacuzzi solar flow submersible pumps may be supplied with special direct current low voltage submersible motors to be connected directly to the solar array.

Additional components may be added included tracking devices to align the array to the sun, energy storage batteries, water storage tanks and interconnection to other electrical supplies.

To achieve maximum performance from systems using Jacuzzi solar flow pumps, the design and selection of equipment is critically important. An authorized Jacuzzi solar flow pump distributor is best qualified to engineer the system for the local environment, specify the components from various manufacturers and install the proper Jacuzzi solar flow submersible to meet requirements.

Jacuzzi Solar Flow Submersible Pumps

Jacuzzi engineers developed this equipment to provide optimum performance from the overall system as well as each component. The Jacuzzi solar flow pump achieves a new level of operating efficiency and reliability.

EFFICIENCY

PUMP designs include an impeller eye seal reducing backflow. Submersed pumping elements perform more efficiently and require no mechanical shaft seal.

MOTOR designs include direct current models. Jacuzzi motors do not require mechanical seal or power converters which absorb energy.

SYSTEMS can be sized for a smaller number of panels due to the wide selection of pumps and the direct connected, direct current brush-type motor (Pat. Pending).

RELIABILITY

PUMP elements are production units from Jacuzzi Inc., a worldwide water system pump manufacturer. Since the pump is submersed, it is self-priming.

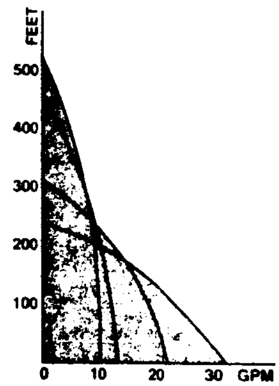
MOTORS are available with direct current brush design (Pat. Pending) providing years of operation between maintenance cycles. Models have a magnetic coupling which eliminates the shaft seal and disengages upon overload conditions.

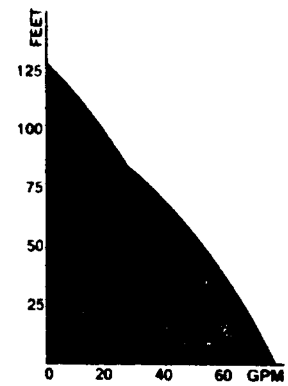
SYSTEMS can be provided in pure direct current eliminating electronic power converters. The pump and motor are installed underground away from vandals and the weather.

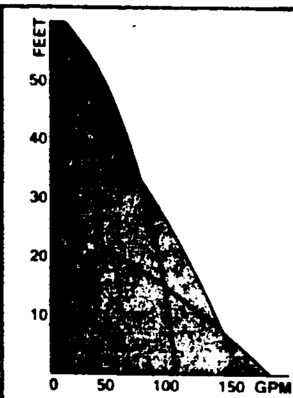
COST-EFFECTIVE

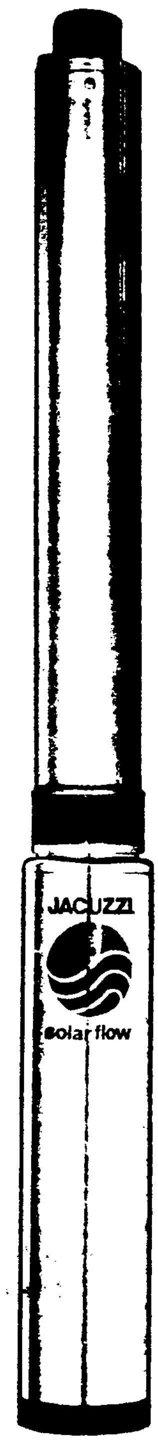
The efficiency and reliability of individual components results in new economies for solar-powered pumping. The extensive range of Jacuzzi solar flow pump models makes it possible to match solar pump systems to needs in the field.

APPROXIMATE PUMPING PERFORMANCE



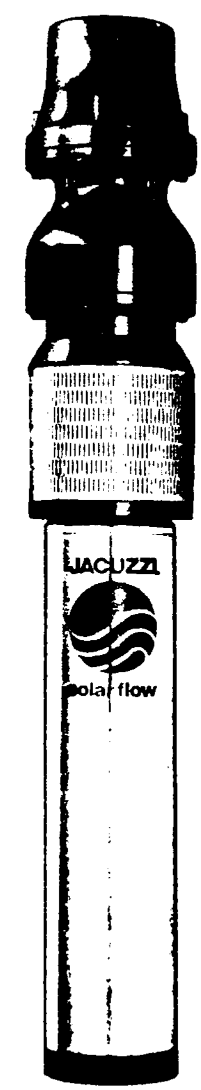






Models SJ1B, C, D, E
Capacity up to 25 GPM

Models SJ1F, G
Capacity up to 60 GPM



Models SJ1M, N, Q
Capacity up to 150 GPM

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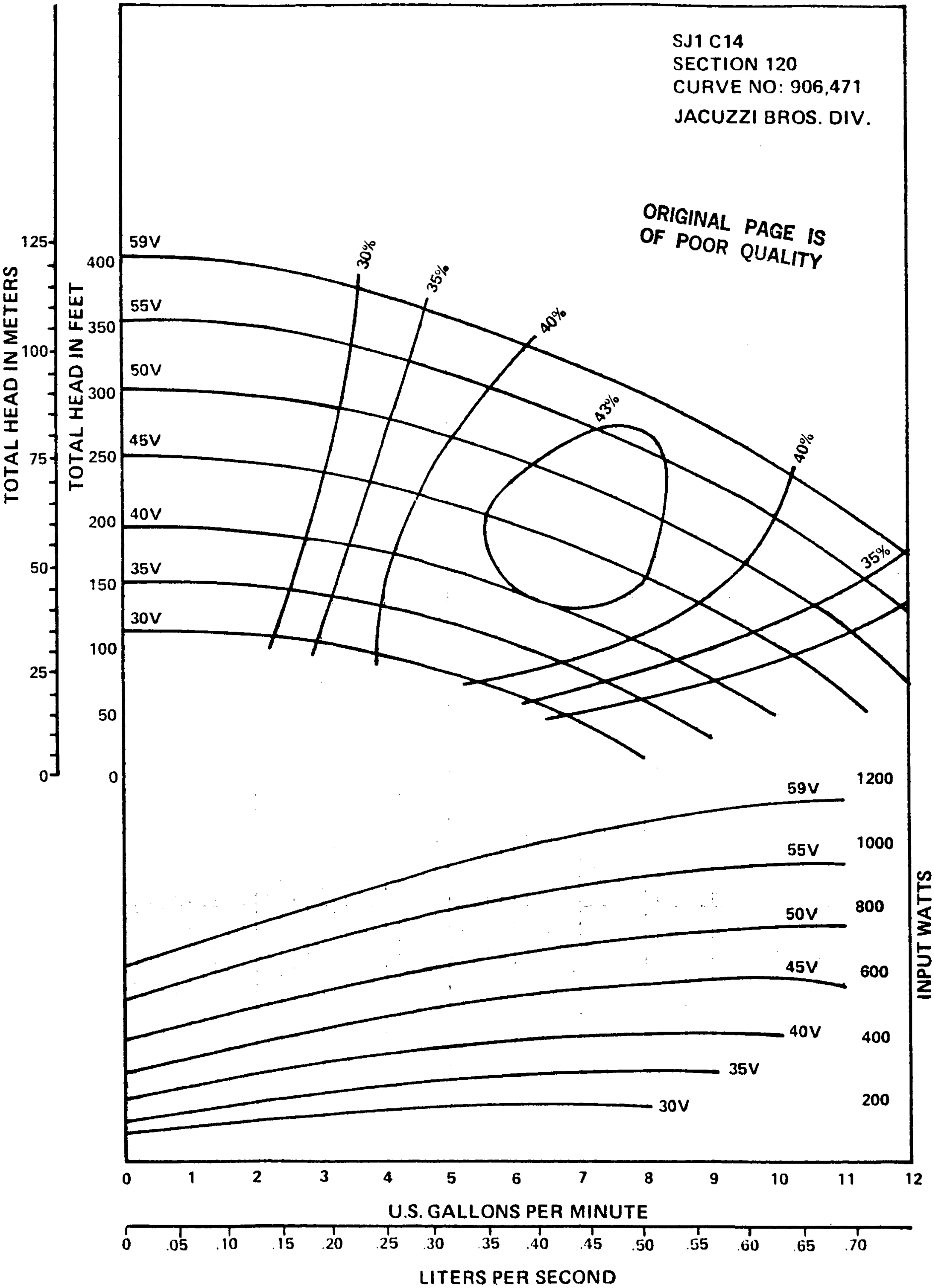
SJ1 C14
SECTION 120
CURVE NO: 906,471
JACUZZI BROS. DIV.
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TOTAL HEAD IN METERS
TOTAL HEAD IN FEET
59V
55V
50V
45V
40V
35V
30V
30%
35%
40%
43%
40%
35%
INPUT WATTS
1200
1000
800
600
400
200
U.S. GALLONS PER MINUTE
LITERS PER SECOND

42 cm portable

SECAM/(PAL)
options 12 V ou 24 V

...es plaisanciers et les caravaniers ont enfin grâce à Salora la possibilité de regarder leurs émissions préférées sur un grand écran de 42 cm o[illegible] 51 cm faible énergie.

La consommation extrêmement basse de 40 watts offre une autonomie considérable aux téléviseurs couleur Salora branchés sur une batterie 12 volts (option référence kit 12 V) ou 24 volts 60 ah (option référence kit 24 V).

Les options sont adaptables à tout moment et permettent ainsi une évolution prévisible de votre téléviseur Salora.

Avec Salora le monde vous appartient

Le téléviseur couleur faible énergie 42 cm Salora avec ses dimensions compactes, son poids léger et son autonomie sur batterie, est le compagnon idéal des voyageurs, des vacanciers, des navigateurs et des inséparables du téléviseur. Il bénéficie de la technique de recherche automatique d'émetteur et du système de mémoire. C'est le seul véritable portable de sa génération.

Grâce à des options adaptables à tout moment, les 42 et 51 cm peuvent recevoir des émissions TV PAL et SECAM et VIDEO NTSC aux standards américains et japonais soit 3.58 et 4.43MHz. Les téléviseurs Salora deviennent ainsi quadri-standard.

Une technologie de pointe les capteurs solaires

Grâce à leur très faible consommation les téléviseurs couleurs Salora 42 et 51 cm peuvent être alimentés par capteur solaire. Il suffit pour cela de disposer d'une option kit 12 V ou 24 V et d'une batterie rechargeable.

L'option Salora (kit solaire) dispose d'un capteur et d'un régulateur de tension qui protègent les circuits des écarts de tension dus aux écarts de luminosité.

Compagnon de plaisance, de promenade, de voyages proches ou lointains le téléviseur couleur portable mérite bien son surnom de "GLOBE TROTTEUR."

Ce téléviseur facilement transportable grâce à sa poignée escamotable dispose de deux antennes incorporées orientables.

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	1G7F	1H7	1G5F	1H5	1H6	1HG	1H1
Taille d'écran	42 cm	42 cm	51 cm	51 cm	56 cm	[illegible]	67 c
Tube high focus, black matrix en 90°	90°	90°	90°	90°	110°	110°	110
Contrôle automatique des fréquences	●	●	●	●	●	●	●
Recherche automatique des fréquences	●	●	●	●	●	●	●
Entrée vidéo directe (prise péritel)	●	●	●	●	●	●	●
Clavier 16 canaux	●	●	●	●	●	●	●
Cellule contraste automatique	—	—	—	●	●	—	●
Télécommande Infra Rouge	○	○	○	○	○	●	○
PAL + SECAM	○	●	○	●	●	●	●
NTSC (4,43 MHz + 3,38 MHz)	○	○	○	○	○	○	○
Réglages grave/aigu	—	—	—	●	●	●	●
Réglages personnalisés	—	—	—	●	●	●	●
Amplificateur Audio (W efficaces)	3 W	5 W	3 W	5 W	5 W	2 x 10 W	5 W
Enceinte bass reflex 2 voies (15 W)	—	—	—	—	○	—	○
Télétexte DE ou GB	—	○	—	○	○	○	○
Réception stéreo (bilingue)	—	—	—	○	○	●	○
Alimentation 12 Volts	○	○	○	—	—	—	—
Alimentation 24 Volts	○	○	○	—	—	—	—
Alimentation solaire (capteur + régulateur)	○	○	○	—	—	—	—
Support à roulettes	—	—	○	○	○	○	○
OIRT	○	○	○	○	○	○	○
Normes de réception TV d'origine	FR	voir 1H	FR	FR.	BE. LU.	DE.	CH.
Kit moniteur — Prises EIAJ + BNC	—	—	○	○	○	○	○
Prise Audio DIN 5 Broches	●	●	●	●	●	●	●
Prise HP supplémentaire	●	●	●	●	●	2	●
Prise Casque jack Ø 6,35 mm	●	●	●	●	●	●	●
Dimensions (LxHxP) cm	50x36x41	50x30x41	60x41x47	60x41x47	67x45x43	67x45x43	75x51
Poids net — kg	17	17	25	25	27	28	34
Garantie 2 ans	●	●	●	●	●	●	●
Consommation horaire (norme CENELEC)	45 W	40 W	45 W	45 W	60 W	62 W	60 W

○ Option ● D'origine

A P P E N D I X C

SIZING REPORTS

GABON VILLAGE POWER PROJECT
DISPENSARY SYSTEMS

REQUIREMENTS AND CONDITIONS

SYSTEM VOLTAGE	=	12 VOLTS
SYSTEM LOAD	=	113.2 AMP-HRS/DAY
SAFETY FACTOR	=	15 %
SUNLESS DAYS	=	10
MINIMUM TEMPERATURE	=	25 C
MAXIMUM TEMPERATURE	=	35 C
WEATHER DATA	=	GABON PER RFP

RECOMMENDED SYSTEM

MSP43E40 MODULES

1	MODULE PER SERIES STRING
16	PARALLEL STRINGS OF MODULES
16	MODULES TOTAL
10	DEGREES SLOPE (FACING TRUE NORTH)
1358	AMP-HRS FOR SUNLESS DAYS
1042	AMP-HRS FOR SEASONAL VARIATIONS
2400	AMP-HRS TOTAL (AT 25 C)

SYSTEM PERFORMANCE

MONTH	MWH/SQCM PER DAY ON HORIZONTAL	MWH/SQCM PER DAY ON ARRAY	ARRAY OUTPUT AMP-HRS PER DAY	LOAD AMP-HRS PER DAY	ARRAY SAFETY FACTOR %	BATTERY % OF FULL CHARGE
JAN	407	383	134	113	18	100
FEB	465	446	156	113	37	100
MAR	407	402	140	113	24	100
APR	465	475	166	113	46	100
MAY	465	490	171	113	51	100
JUN	407	433	151	113	33	100
JUL	349	366	128	113	13	100
AUG	407	420	146	113	29	100
SEP	407	407	142	113	25	100
OCT	407	395	138	113	22	100
NOV	407	385	134	113	19	100
DEC	407	380	133	113	17	100

ARRAY SAFETY FACTOR = 27.9% ANNUAL, 12.8% WORST-MONTH

GABON VILLAGE POWER PROJECT
SCHOOL SYSTEMS (EXCEPT BOLOSSOVILLE)

REQUIREMENTS AND CONDITIONS

SYSTEM VOLTAGE	=	12 VOLTS
SYSTEM LOAD	=	84.0 AMP-HRS/DAY
SAFETY FACTOR	=	15 %
SUNLESS DAYS	=	10
MINIMUM TEMPERATURE	=	25 C
MAXIMUM TEMPERATURE	=	35 C
WEATHER DATA	=	GABON PER RFP

RECOMMENDED SYSTEM

MSP43E40 MODULES

1	MODULE PER SERIES STRING
14	PARALLEL STRINGS OF MODULES
14	MODULES TOTAL
10	DEGREES SLOPE (FACING TRUE NORTH)
1008	AMP-HRS FOR SUNLESS DAYS
792	AMP-HRS FOR SEASONAL VARIATIONS
1800	AMP-HRS TOTAL (AT 25 C)

SYSTEM PERFORMANCE

MONTH	MWH/SQCM PER DAY ON HORIZONTAL	MWH/SQCM PER DAY ON ARRAY	ARRAY OUTPUT AMP-HRS PER DAY	LOAD AMP-HRS PER DAY	ARRAY SAFETY FACTOR %	BATTERY % OF FULL CHARGE
JAN	407	383	117	84	39	100
FEB	465	446	136	84	62	100
MAR	407	402	123	84	46	100
APR	465	475	145	84	73	100
MAY	465	490	150	84	78	100
JUN	407	433	132	84	57	100
JUL	349	366	112	84	33	100
AUG	407	420	128	84	53	100
SEP	407	407	124	84	48	100
OCT	407	395	121	84	44	100
NOV	407	385	118	84	40	100
DEC	407	380	116	84	38	100

ARRAY SAFETY FACTOR = 50.8% ANNUAL, 33.0% WORST-MONTH

GABON VILLAGE POWER PROJECT
VILLAGE LIGHT

REQUIREMENTS AND CONDITIONS

SYSTEM VOLTAGE = 12 VOLTS
SYSTEM LOAD = 15.1 AMP-HRS/DAY
SAFETY FACTOR = 15 %
SUNLESS DAYS = 10
MINIMUM TEMPERATURE = 25 C
MAXIMUM TEMPERATURE = 35 C
WEATHER DATA = GABON PER RFP

RECOMMENDED SYSTEM

MSP43E40 MODULES

1 MODULE PER SERIES STRING
2 PARALLEL STRINGS OF MODULES
2 MODULES TOTAL
10 DEGREES SLOPE (FACING TRUE NORTH)
151 AMP-HRS FOR SUNLESS DAYS
59 AMP-HRS FOR SEASONAL VARIATIONS
210 AMP-HRS TOTAL (AT 25 C)

SYSTEM PERFORMANCE

MONTH	MWH/SQCM PER DAY ON HORIZONTAL	MWH/SQCM PER DAY ON ARRAY	ARRAY OUTPUT AMP-HRS PER DAY	LOAD AMP-HRS PER DAY	ARRAY SAFETY FACTOR %	BATTERY % OF FULL CHARGE
JAN	407	383	16.70	15.10	11	100
FEB	465	446	19.45	15.10	29	100
MAR	407	402	17.53	15.10	16	100
APR	465	475	20.71	15.10	37	100
MAY	465	490	21.36	15.10	41	100
JUN	407	433	18.88	15.10	25	100
JUL	349	366	15.96	15.10	7	100
AUG	407	420	18.31	15.10	21	100
SEP	407	407	17.75	15.10	18	100
OCT	407	395	17.22	15.10	14	100
NOV	407	385	16.79	15.10	11	100
DEC	407	380	16.57	15.10	10	100

ARRAY SAFETY FACTOR = 19.9% ANNUAL, 6.7% WORST-MONTH

GABON VILLAGE POWER PROJECT
BOLOSSOVILLE COMMUNITY CENTER

REQUIREMENTS AND CONDITIONS

SYSTEM VOLTAGE	=	12 VOLTS
SYSTEM LOAD	=	74.0 AMP-HRS/DAY
SAFETY FACTOR	=	15 %
SUNLESS DAYS	=	10
MINIMUM TEMPERATURE	=	25 C
MAXIMUM TEMPERATURE	=	35 C
WEATHER DATA	=	GABON PER RFP

RECOMMENDED SYSTEM

MSP43E40 MODULES

1	MODULE PER SERIES STRING
14	PARALLEL STRINGS OF MODULES
14	MODULES TOTAL
10	DEGREES SLOPE (FACING TRUE NORTH)
888	AMP-HRS FOR SUNLESS DAYS
912	AMP-HRS FOR SEASONAL VARIATIONS
1800	AMP-HRS TOTAL (AT 25 C)

SYSTEM PERFORMANCE

MONTH	MWH/SQCM PER DAY ON HORIZONTAL	MWH/SQCM PER DAY ON ARRAY	ARRAY OUTPUT AMP-HRS PER DAY	LOAD AMP-HRS PER DAY	ARRAY SAFETY FACTOR %	BATTERY % OF FULL CHARGE
JAN	407	383	117	74	58	100
FEB	465	446	136	74	84	100
MAR	407	402	123	74	66	100
APR	465	475	145	74	96	100
MAY	465	490	150	74	102	100
JUN	407	433	132	74	79	100
JUL	349	366	112	74	51	100
AUG	407	420	128	74	73	100
SEP	407	407	124	74	68	100
OCT	407	395	121	74	63	100
NOV	407	385	118	74	59	100
DEC	407	380	116	74	57	100

ARRAY SAFETY FACTOR = 71.2% ANNUAL, 51.0% WORST-MONTH

GABON VILLAGE POWER PROJECT
BOLOSSOVILLE SCHOOL

REQUIREMENTS AND CONDITIONS

SYSTEM VOLTAGE	=	12 VOLTS
SYSTEM LOAD	=	62.0 AMP-HRS/DAY
SAFETY FACTOR	=	10 %
SUNLESS DAYS	=	10
MINIMUM TEMPERATURE	=	25 C
MAXIMUM TEMPERATURE	=	35 C
WEATHER DATA	=	GABON PER RFP

RECOMMENDED SYSTEM

MSP43E40 MODULES

1	MODULE PER SERIES STRING
8	PARALLEL STRINGS OF MODULES
8	MODULES TOTAL
10	DEGREES SLOPE (FACING TRUE NORTH)
744	AMP-HRS FOR SUNLESS DAYS
456	AMP-HRS FOR SEASONAL VARIATIONS
1200	AMP-HRS TOTAL (AT 25 C)

SYSTEM PERFORMANCE

MONTH	MWH/SQCM PER DAY ON HORIZONTAL	MWH/SQCM PER DAY ON ARRAY	ARRAY OUTPUT AMP-HRS PER DAY	LOAD AMP-HRS PER DAY	ARRAY SAFETY FACTOR %	BATTERY % OF FULL CHARGE
JAN	407	383	66.8	62.0	8	100
FEB	465	446	77.8	62.0	25	100
MAR	407	402	70.1	62.0	13	100
APR	465	475	82.8	62.0	34	100
MAY	465	490	85.5	62.0	38	100
JUN	407	433	75.5	62.0	22	100
JUL	349	366	63.8	62.0	3**	100
AUG	407	420	73.2	62.0	18	100
SEP	407	407	71.0	62.0	14	100
OCT	407	395	68.9	62.0	11	100
NOV	407	385	67.1	62.0	8	100
DEC	407	380	66.3	62.0	7	100

ARRAY SAFETY FACTOR = 16.8% ANNUAL, 3.0% WORST-MONTH

** SCHOOL NOT IN SESSION, NOT CONSIDERED IN DESIGN

A P P E N D I X   D

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VILLAGE DISPENSARY PHOTOVOLTAIC POWER SYSTEM

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